INSTREAM PUBLIC USES, OUTSTANDING CHARACTERISTICS, AND RESOURCES OF THE LAMPREY RIVER AND PROPOSED PROTECTIVE FLOW MEASURES FOR FLOW DEPENDENT RESOURCES

FINAL REPORT

NOVEMBER 2006

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

NHDES-R-WD-06-49

INSTREAM PUBLIC USES, OUTSTANDING CHARACTERISTICS, AND RESOURCES OF THE LAMPREY RIVER AND PROPOSED PROTECTIVE FLOW MEASURES FOR FLOW DEPENDENT RESOURCES

FINAL REPORT

Prepared for
STATE OF NEW HAMPSHIRE
Department of Environmental Services

Prepared by
NORMANDEAU ASSOCIATES
University of Massachusetts
University of New Hampshire

November 2006

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Table of Contents

Page

List of Figures

List of Tables

Glossary

ACOE	U.S. Army Corps of Engineers
ADO	Affected dam owner
AMC	Appalachian Mountain Club
AWU	Affected water user
BSI	Basin stress index
cfs	Cubic feet per second
cfsm	Cubic feet per second per square mile
CUT	Continuous under threshold
FTM	Floodplain transect method
GIS	Geographic information system
GPS	Global positioning system
HMU	Hydromorphological unit
IHA	Indicators of hydrologic alteration
IPUOCR	Instream public uses, outstanding characteristics and resources
LBFC	Lamprey baseline fish community
MesoHABSIM	A computer simulation of meso-scale habitat
NAI	Normandeau Associates, Inc.
NFP	Natural flow paradigm
NHDES	New Hampshire Department of Environmental Services
NHF&GD	New Hampshire Fish & Game Department
NHI	Natural heritage inventory
NHNHB	New Hampshire Natural Heritage Bureau
NRCS	Natural Resources Conservation Service
PHABSIM	Physical habitat simulation model
PISF	Protected instream flow
POTW	Publicly owned treatment works
RSA	Revised statutes annotated
RTE	Rare, threatened and endangered species
TFC	Target fish community
TMDL	Total maximum daily load
TRC	Technical review committee
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WMP	Water management plan
WMPA	Water management planning area
WMPAAC	Water management planning area advisory committee
WWTP	Wastewater treatment plant

1.0 INTRODUCTION AND PURPOSE

The primary objective of this effort is to establish a comprehensive list of flow dependent Instream Public Uses, Outstanding Characteristics and Resources (IPUOCR) entities for the designated reach of the Lamprey River (from the Epping/Lee town line to Durham/Newmarket town line) and to propose methods for assessing their flow dependence. Based on their seasonal flow requirements, these IPUOCR entities will serve as guideposts for designating protected instream flows.

The IPUOCR evaluated included the list developed by the New Hampshire Department of Environmental Services (NHDES 2004) as a starting point augmented by literature searches, stakeholder consultation and a field visit. Such information included, but was not limited to, designated river nomination reports, river corridor management plans, natural resources studies, natural heritage inventories and environmental assessments and impact statements.

A preliminary draft IPUOCR list was created in August 2005. The preliminary draft IPUOCR list and supporting information was refined following review and comment by NHDES and the advisory committees and is the basis for the discussion of resources in this final IPUOCR report. In this report, the development of the final IPUOCR list is described. The final IPUOCR list was divided into flow dependent and non-flow dependent entities. Protected flows will not be determined for the non-flow dependent entities. Approaches for establishing protected instream flows (PISF) for flow dependent IPUOCR are presented in Section 3.1. Non-flow dependent entities are identified in Section 3.2.

IPUOCRs located upstream of the designated segment of the Lamprey River were not identified or cataloged as part of this study since under Env-Ws 1905.02 the PISF study is limited to the designated river segment. Identified Affected Water Users (AWU) and Affected Dam Owners (ADO) upstream of the designated segment will be identified and evaluated during the preparation of the Water Management Plan (WMP) to be prepared for the Lamprey River. The discussion of the development of the WMP is not included in this report and is a separate task in the PISF process.

The results of the evaluation of the flow dependent IPUOCR entities will ultimately lead to the development of recommended PISF for the Lamprey River. The conceptual foundation for evaluation of the IPUOCR entities and the development of the PISF values is the Natural Flow Paradigm (NFP) (Poff et al. 1997). The NFP has emerged over the past decade as a widely accepted framework for describing the roles of stream flow in shaping ecological characteristics of streams and understanding the consequences of modifications to natural stream flow patterns by human activity.

Considerable evidence has been presented (Naiman et al. 2002) to support the view that healthy aquatic ecosystems (instream and riparian) are dependent upon maintaining the natural flow variability of stream and rivers. Within the NFP, natural flows are the controlling factor in the development of the aquatic ecosystem and the maintenance of natural flow patterns is believed to be necessary to ensure its sustainability. Because these natural flow patterns are variable and dynamic the NFP recognizes the importance of considering stream flow in terms of a *regime* rather than describing it with a single number. Flow regime reflects the dynamic nature of the hydrology of the river in that it varies over time in response to changes in several variables such as precipitation, runoff, groundwater interactions, and evapotranspiration, which occurs over a broad range of spatial and temporal scales.

Flow regimes can be described in terms of five general attributes that characterize temporal patterns that are particularly linked to aquatic ecosystems include flow:

- Magnitude (high to low)
- Timing or predictability (season, week or month)
- Frequency (number of times a year)
- Duration (days, weeks, months)
- Rate of change (hours, days, weeks, months)

The variability of flow regime influences ecological integrity by either directly or indirectly influencing such factors as water quality, physical habitat and biotic interactions (Poff et al. 1997). Human alterations to any of the components of the natural flow regime may result in impacts to the river ecosystem. Understanding the potential for the human alteration of the natural flow regime of the Lamprey River and its potential impact to the river's flow dependent IPUOCRs is one of the major facets of the PISF study and in the development of the WMP.

2.0 METHODS OF ASSESSMENT

2.1 OVERVIEW OF ALL POTENTIAL IPUOCRS

The NHDES has defined the categories of IPUOCRs that must be evaluated and included in the development of a PISF Study and eventual WMP. Categories of potential IPUOCR include the following:

Navigation: The use of the river for non-recreational, transportation purposes.

Recreation: Use of the river for swimming, boating or significant shoreland recreation such as hiking, camping, picnicking and bird watching.

Fishing: Both recreational use and commercial use.

Storage: Natural or man-made attributes of a river for water storage.

Conservation/Open Space**:** Issues concerning management of open space, conservation easements or municipal, state or federal parks.

Maintenance and Enhancement of Aquatic and Fish Life*:* Those aquatic dependent species that make up a balanced, integrated and adaptive community of organisms having a species composition, diversity and functional organization comparable to that of similar natural habitats of a region.

Fish and Wildlife Habitat: Species that rely on flow and flow to regions which are important to the survival of fish and wildlife populations, including but not limited to: spawning and feeding beds, waterfowl breeding or wintering areas, freshwater wetlands or riparian habitat.

Rare, Threatened or Endangered (RTE): fish, wildlife, vegetation or natural/ecological communities: As listed by New Hampshire Natural Heritage Inventory (NHI) and nomination papers.

Water Quality Protection/Public Health: Characteristics that maintain water quality of the river including, but not limited to, chemical and physical parameters that support designated and existing uses.

Public Water Supply: An existing source of public drinking water as defined in Env-Ws 302.02.

***Pollution Abatement*:** Wastewater treatment facilities or industrial treatment facilities and aspects of flow affecting assumptions of flow for dilution and dispersal of waste in mixing zones and the river's overall capacity to mitigate natural and non-point source contamination.

Aesthetic Beauty/Scenic: Including but not limited to designated viewing areas, scenic vistas and overlooks.

Cultural: On-going river corridor management planning effort or other local efforts to protect or manage the river, riverside parks or other public areas, or community support for riverfront revitalization.

Historical or Archaeological: Based on the presence or absence of known historical or archaeological resources.

Community Significance: A natural, managed, cultural or recreational resource or use thereof associated with the river that is recognized by local residents or a municipal document as being important to the community adjacent to the river.

***Hydrological/Geological**:* A national, regional, state or local resource as determined by the state geologist or as listed in a national or state resource assessment.

***Agricultural*:** As defined by RSA 21:34a.

2.2 DRAFT LIST OF IPUOCR ENTITIES

From the universe of potential IPUOCR, the project team developed in August 2005 a draft list that included IPUOCR that were confirmed to be present along the designated segment or suspected to be present. Natural history and location information was reviewed for each IPUOCR entity, and compared to the initial criteria for assigning an IPUOCR plant or wildlife species or natural community or other entity to a flow dependency category. The flow based criteria were:

Flow Dependent – Species with one or more life stages requiring flowing water within banks of the river channel of the designated segment; or a community that provides habitat for such species as an important function were included in this category. Other entities such as canoeing and kayaking were included in this category if they were determined to be reliant on flow.

Potentially Flow Dependent – Entities with an unclear link to flow were included in this category as well as entities with known flow dependence but unknown or unconfirmed presence in the designated segment. A determination of flow dependence was made for these entities after further literature review and the site visit.

Non-Flow Dependent – Entities in this category met none of the above criteria. The life cycles of species or activities associated with the entities in this category were not dependent on water flow or levels within the river channel or floodplain of the designated segment at any time of the year. These entities do not depend on flow.

The draft list was delivered to NHDES on August 18, 2005 and subsequently distributed within the NHDES, to the Technical Review Committee (TRC), and the Water Management Planning Area Advisory Committee (WMPAAC). There were few comments received on the draft list therefore the draft list and observations from the site visit formed the basis for the final list of IPUOCR for the designated segment of the Lamprey River. This list was delivered to the NHDES on September 23, 2005 and subsequently distributed to the members of the WMPAAC and TRC. The draft final IPUOCR list was presented to the WMPAAC on October 7, 2005 at a public meeting in Raymond, NH. The draft final list reclassified potentially flow dependent resources into either flow dependent or non-flow dependent categories.

2.3 LITERATURE REVIEW

Numerous sources of information describing the resources of the Lamprey River have been reviewed including the Lamprey Wild and Scenic River Report (LWSRS 1995), several reports detailing Lamprey river ecology, and water monitoring data (NHDES 1995). Other available information reviewed included the Natural Resources Conservation Service (NRCS) soil maps, National Wetland Inventory maps, geologic resource maps, GRANIT GIS layers and aerial photos.

The review of available information was structured to develop the information necessary to prepare a preliminary list of IPUOCR entities for the designated segment and to annotate each entity on the basis of river location and dependence on flow conditions. This preliminary list was confirmed to the extent possible and supplemented, where necessary, through consultation with state and local government and the field survey.

2.4 CONSULTATION

Agencies and organizations contacted by Normandeau Associates, Inc. (NAI) or the NHDES included groups such as Lamprey Technical Review Committee (TRC) and Water Management Planning Area Advisory Committee (WMPAAC) members, New Hampshire Natural Heritage, Lamprey River Advisory Committee, Lamprey River Watershed Association, New Hampshire Fish and Game Department (NHF&GD) and the relevant conservation commissions. New information from these groups was added to the GIS database and used to describe the IPUOCR entities.

2.5 FIELD SURVEY

A field survey was conducted August 25-26, 2005 to verify the existence and occurrence of the IPUOCR entities. The purpose of the instream habitat and aquatic fauna survey of the Lamprey River was to identify instream public uses, outstanding characteristics and resources (IPUOCRs). This two day field survey of the entire designated segment included stops at specific prescreened locations to document the presence of each entity or the presence of conditions or habitat suitable for each entity. Candidate locations for field verification were determined from data compiled by NHDES, New Hampshire Natural Heritage data and information obtained from watershed groups. The intent was to ensure that examples of critical locations of flow dependent or potentially flow dependent resources were visited.

In addition to the instream habitat and aquatic fauna survey, a riparian and upland survey was also performed during the field survey to identify the presence or absence of listed resources. This survey was guided by a set of maps which presented the available geographic information on the critical resources of the designated segment along with points to be visited. At each stop, the resources on the map were confirmed and photo documented according to the NHDES photo documentation procedures. The photos were geo-referenced using a Global Positioning System (GPS) receiver and added as a layer to the GIS database (Figures 2-1 and 2-2). Occurrences of resources not represented in the existing database were also documented.

Due to delays in contracting as well as to the dramatic increase in river flow associated with rain events and water releases from the upstream lakes and ponds, the detailed survey of instream habitat distribution had to be postponed to the next field season for reasons of safety. Three reconnaissance level visits were conducted on February 18, 2005, October 3, 2005 and November 18, 2005. Discussion of the preliminary IPUOCR identification results are presented later in this report.

2.6 Delineations of Sections and Reaches

Based on field observations together with analysis of high resolution aerial photographs taken in February 2005, the designated portion of the river was delineated into seven sections, based on their habitat characteristics. In these sections, similar habitats and species could be assumed to be potentially present.

Aerial photographs and visual observation of the river indicate the form varies throughout its length (Figure 2-3). Characteristics such as oxbows and meanders can be determined from maps and photographs, while substrate, width, depth and other characteristics need to be viewed at the fine scale. Flow has the ability to alter the morphology of the river. The Lamprey River channel cuts through numerous ledges that define its morphological character. The morphological character of the Lamprey ranges from a high gradient, straightened third order stream to a low gradient meandering fourth order river and 46 % of the designated area is impounded. Figure 2-3 shows the location of the seven sections identified for the designated segment of the Lamprey River:

Section I – The high gradient portion of the designated segment is located directly downstream of the confluence of the North River, where it is constricted by bedrock outcrops. This section is one of the few free, but slow flowing portions of the Lamprey River accompanied by forest and wetlands. The section ends with a former impoundment upstream of Wadleigh Falls.

Section II – Downstream of the partially breached dam at Wadleigh Falls the river first splits into two channels surrounding an island. Below the island the straight alignment causes us to speculate on the possibility of some historical channelization or entrenchment. The river is about 20 m wide, with a relatively high gradient and almost closed canopy cover.

Section III – Begins where the Lamprey River makes an almost 180 turn adjacent to Tuttle Swamp at Newmarket Plains. Downstream the river begins to wind between the hills and in the forest and is still relatively narrow (about 20 m). Just upstream of Lee Hook Road the river widens to 30 m and slows down due to the backwater effect created by bedrock outcropping and rapids just upstream and downstream of the Lee Hook Road bridge.

Section IV – Begins at the bedrock controlled rapids located immediately downstream of the Lee Hook Road bridge. Below the rapids the river widens into a large shallow glide and then transitions into a meandering channel comprised of runs and pools which end at Hook Island and the beginning of the next section.

Figure 2-1. Locations of dams and other features in the Lamprey River watershed.

Figure 2-2. Locations of NWI Wetlands and Natural Heritage data.

Figure 2-3. Locations of the seven sections identified for the Lamprey River designated segment.

Section V – Is the impoundment upstream of Wiswall Dam, where this section ends.

Section VI – From below Wiswall Dam to below Packers Falls there is a series of bedrock outcrops that created the multiple waterfalls, rapids and pools of this section.

Section VII – From shortly downstream of Packers Falls the river is impounded to the end of the designated segment at the Durham/Newmarket town line.

2.7 SCREENING METHODS

The IPUOCR list contained in the draft was augmented with a literature review and observations from the field reconnaissance survey. The revised list was then split into two categories based on the dependence of the entity on stream flow. These categories were flow dependent, which included resources with specific well established flow requirements, and non-flow dependent. Potentially flow dependent resources from the draft list were assigned to either flow dependent or non-flow dependent categories.

The non-flow dependent IPUOCR are discussed, but are not expected to be addressed further in this study. The flow dependent resources are also discussed along with proposed methods of assessment to be used to establish a protective instream flow (PISF) for each resource requiring an acceptable minimum flow. Resources requiring flows other than acceptable minimums (appropriate average or floods flows for example) are also discussed. A flowchart describing the screening process for flow dependent resources is provided in Figure 2-4.

2.8 FLOW DEPENDENCE AND CRITICAL FLOW RELATED CHARACTERISTICS OF IPUOCR ENTITIES

The list of IPUOCR entities for the Lamprey River is extensive. However, many of these entities are not flow dependent. The matrix presented in Table 2-1 contains information from the preliminary list, literature review and the reconnaissance site visit. All IPUOCR entities were then classified as either flow dependent or non-flow dependent based on information known to the project team to date. Categories in the matrix include: the resource; the reason for inclusion; the local, regional and national importance of the resource; and the flow requirement of the resource including seasonality and duration, if known. Critical Flow categories of “High”, “Average”, and “Low” were assigned to IPUOCR if they were believed to be most sensitive to deviations from the natural flow paradigm (NFP) at high, average, or low flows during flow dependent life stages or operations. Flow deviations include changes in frequency, timing, duration and/or magnitude. For example, hibernating wood turtles can be harmed by drops in winter flows when exposure and freezing occur, while changes in the magnitude and duration of high, low, or average flows (outside the range of the NFP) could alter emergent wetland functions and species associations.

The specific locations of resources that are rare, threatened or endangered were reviewed to the extent they were available, but they are not presented. Likewise, infrastructure information (dams, POTWs, water supplies) that is a potential security risk was reviewed, but is not presented. The NHDES will make the ultimate decision on whether or not to publish these data.

The resulting matrix of flow dependent IPUOCR entities provides essential information needed to screen candidate methods for the determination of PISF. If an IPUOCR entity was determined to be dependent on an acceptable minimum flow, a procedure to determine an acceptable minimum PISF is proposed (Section 3). If an IPUOCR entity was determined to be dependent on an acceptable average or high flow, a method is needed to determine the PISF for those IPUOCR entities. Eventually, the universe of potential and practical water management alternatives will be determined for the Lamprey.

3.0 DISCUSSION OF IPUOCR ENTITIES AND PISF METHODS

3.1 FLOW DEPENDENT IPUOCRS

This section includes all flow dependent IPUOCR entities of the Lamprey River under their IPUOCR classifications as presented in Table 2-1. This discussion includes information describing the IPUOCR entities followed by the proposed method for determining protected flows for each type classification. The flow needs for each IPUOCR will be determined as described below and compiled. This compilation will provide the basis for the PISF target flow regime to be maintained under the WMP.

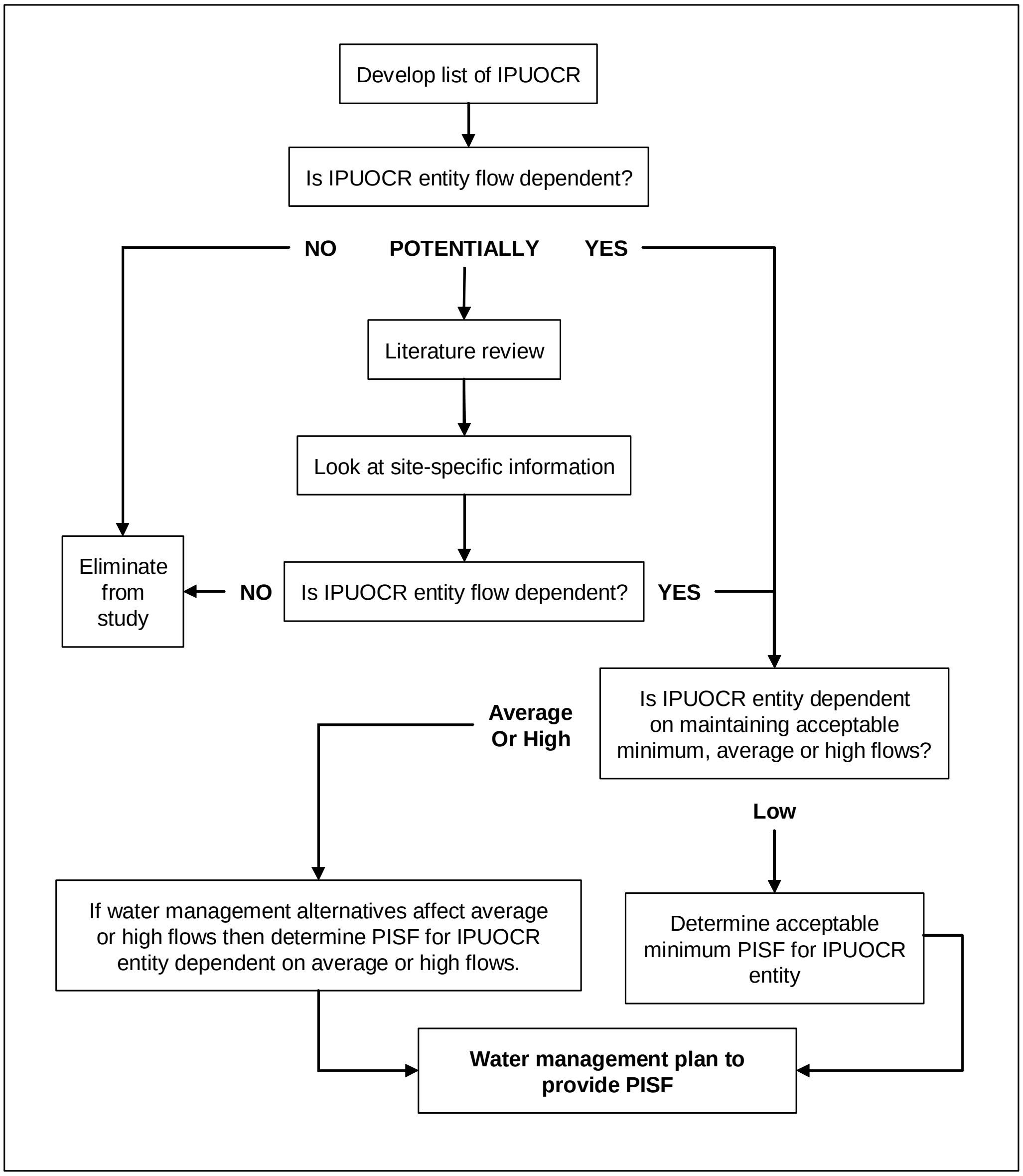

Figure 2-4. Flow chart of IPUOCR screening process.

Table 2-1. Matrix of IPUOCR's including flow dependence, reason for inclusion, critical seasons, life stages and method of assessment.

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Recreation	Boating		Yes	High, Ave		Sp, F	Determine flow needs through observation and boater interviews
	Swimming		Yes			Su	Swimmer interviews
	Shoreland Recreation		No			All	
Storage	Wiswall Dam	Durham	No				
Fishing	Recreational		Yes	Low	Adults	All	MesoHABSIM
Conservation / Open Space			No				
Maintenance and Enhancement of Aquatic Fish and Life	Native Fish		Yes	All	All	All	MesoHABSIM
	Introduced Fish		Yes	All	All	All	MesoHABSIM
	Anadromous Fish		Yes	All	All	All	MesoHABSIM
	Mussels		Yes	All	All	All	MesoHABSIM
	Insects		Yes	All	All	All	MesoHABSIM
Fish and Wildlife Habitat	Fish Life Stage Habitats		Yes	All	All	All	MesoHABSIM
	Lower Floodplain Forest		Yes	High, Avg.	All	Sp	Floodplain transect
	Higher Floodplain Forest		Yes	High	All	Sp	Floodplain transect
	Alluvial Red Maple Swamp		Yes	Avg, Low	All	Sp, Su	Floodplain transect
	Oxbow and Backwater shrub swamps, marshes, ponds		Yes	All	All	Su	Floodplain transect
	Floodplain Vernal Pool Species		Yes	High, Avg	Eggs, Larvae	Sp, Su	Floodplain transect
	Mesic-Wet High Energy Riverbank		Yes	All	All	Su	Floodplain transect
	River Rapids		Yes	All	All	Su	Floodplain transect

(continued)

Table 2-1. (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
RTE Fish, Wildlife, Vegetation or Natural/Ecological Communities	Bridle Shiner		Yes	All	All	All	MesoHABSIM
	Banded Sunfish		Yes	All	All	All	MesoHABSIM
	Brook Trout		Yes	All	All	All	MesoHABSIM
	Redfin Pickerel		Yes	All	All	All	MesoHABSIM
	Swamp Darter		Yes	All	All	All	MesoHABSIM
	Brook Floater		Yes	All	All	All	MesoHABSIM
	Blanding’s Turtle		Yes	Avg, Low	Juv, Adult	All	Floodplain transect
	Wood Turtle		Yes	Low, High	Juv, Adult	W, Su	Floodplain transect
	Spotted Turtle		Yes	Avg, Low	Juv, Adult	All	Floodplain transect
	Osprey	Newmarket Durham	Yes	Low, Avg	Nesting, Adult	Sp, Su	Floodplain transect
	Bald Eagle	Newmarket	Yes	High, Avg	All	W, Sp	MesoHABSIM
	Sedge Wren	Durham	Maybe	High, Avg	Nesting	Sp, Su	Floodplain transect
	Pied-billed Grebe	Patchy	Yes	High, Avg, Low	Nesting	Sp, Su	Floodplain transect
	Climbing Hempweed		Yes	Avg, High	All		Floodplain transect
	Small-crested Sedge		Yes		All		Floodplain transect
	Star Duckweed		Yes	Avg,	All	Sp, Su	Floodplain transect
	Sharp-flowered Mannagrass		Yes		All		Floodplain transect
	Water Marigold	Newmarket	Yes	High, Low	All	Sp, Su	Floodplain transect
	Small Beggars Tick		Yes		All		Floodplain transect
	Knotty Pondweed		Yes	Low	All	Sp	Floodplain transect
	Slender Blueflag		Yes		All		Floodplain transect
	Swamp White Oak Floodplain Forest		Yes	High	All	Sp	Floodplain transect
	Peregrine Falcon		No				
	Eastern hog-nosed Snake		No				
	Philadelphia Panic Grass		No				
	Northern Blazing Star		No				
	Blunt-lobed Woodsia		No				
	Missouri Rock Cress		No				
	Downy False Foxglove		No				

(continued)

Table 2-1. (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Water Quality Protection and Public Health			No				
Public Water Supply	Durham-UNH water withdrawal	Durham	Yes			Su	MesoHABSIM and Floodplain Transect
Pollution Abatement	Epping WWTF	Epping	No				
Aesthetic Beauty / Scenic	Wild and Scenic River Status		No				
Cultural			No				
Historical or Archaeological	Wiswall Falls Mill site Wadleigh Falls	Durham Lee	No				
Community Significance			No				
Hydrological / Geological			No				
Agricultural	Four properties	Lee	No				

As mentioned previously, the PISF will be determined within the context of the Natural Flow Paradigm (NFP). NFP recognizes that there are times when flows will naturally be higher or lower, and that these flows vary in duration and frequency. The natural hydrograph of the river is the framework for identifying the ranges of magnitude, frequency and duration of flows and when they will occur. PISF that follow the NFP will be protective of the native ecosystem that evolved under those flows. Even droughts occur naturally with a certain frequency and duration that would allowed under the WMP. PISF will be determined that identify the duration and frequency of certain magnitudes of flow and when during the year they need to be maintained.

3.1.1 Recreation

Flow dependent recreational IPUOCRs include boating and swimming. The entirety of the designated portion of the Lamprey River provides opportunities for recreational flatwater and whitewater canoeing and kayaking. The river conditions for boating through the designated segment are described in the AMC's River Guide (AMC 2002), which divides the river into two sections. The river section from the Epping town line to Wadleigh Falls is described by the AMC River Guide (AMC 2002) as consisting of quickwater with areas of Class II ledge. Quickwater is a level of difficulty for boating and is defined as fast moving water, "where its surface is nearly smooth at high water levels, but is likely to be choppy at medium water levels and shallow at low water levels" (AMC 2002). Class II is the difficulty of rapids in a section and in this section they are considered as novice. River conditions encountered in Class II rapids would include "straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers" (AMC 2002).

The river section from Wadleigh Falls to the Newmarket town line is described as consisting of flatwater, quickwater and Class I and III whitewater (AMC 2002). Flatwater is defined as having little to no current, smooth surface and paddling upstream is easy (AMC 2002). Class I to III rapids would range from easy to intermediate, where intermediate is described as "rapids with moderate irregular waves which may be difficult to avoid and which can swamp an open canoe" (AMC 2002). Within this reach the Packers Falls area is rated as a Class III run during the spring season and as a Class II run well into the summer. The above two sections of the designated segment are listed as passable during high to medium water during the spring and summer seasons. The project team was able to navigate the majority of the designated segment (excluding the Wiswall Dam to Packers Falls section), by boat, on August 25 and 26, 2005. Flow during this time period was 18 to 23 cubic feet per second (cfs) at the USGS Packer's Falls gage, which is considered low.

Opportunities for swimming are available throughout the designated segment. There are four designated beaches located within the designated river segment in the town of Lee: Wellington Camping Park, Ferndale Acres, Wadleigh Falls Campground and Glenmere Village Association. In addition to the designated beaches, areas frequented by swimmers include the areas around Wadleigh Falls, Wiswall Dam, and Packers Falls. Much of the swimming conducted in the river occurs in impounded sections that are relatively insensitive to flow. During high flow periods, swimming in the fastwater, rapids, and falls sections of the river is considered ill-advised and dangerous.

Proposed Assessment Methods for Recreation

Boating flows will be evaluated qualitatively through a combination of the observations of the field teams and interviews of boaters on the river during various river stages. These stages will include low summer flows and high spring flows. The interviews will include a survey of boater's use of the river (season run, frequency of visits and favorite sections), flow conditions (preferred flow levels, maximum and minimum flows run) and sources of information on flow conditions. The team will also coordinate with local paddling groups to develop a consistent interview format and to target appropriate time and flow windows for both kayakers and canoeists. If any water management alternatives considered in the WMP include substantial changes in average or peak flows, this IPUOCR entity may need to be evaluated more quantitatively.

Swimmers using designated beaches will be interviewed as they are encountered on the river during the summer and the results will be evaluated qualitatively. The interviews will include a survey of swimmer's use of the river (frequency of visits and favorite swimming areas), flow conditions (preferred flow levels) and sources of information on flow conditions. If any water management alternatives considered in the WMP include substantial changes in flows or water levels that may impact swimming, this IPUOCR entity may need to be evaluated more quantitatively.

3.1.2 Fishing

The majority of the fishing in the river is for stocked trout. The Lamprey River is regularly scheduled for stocking, and its stocking schedule can be found on the NHF&GD website (www.wildlife.state.nh.us/Fishing/fishing.htm). The species stocked in the river for 2005 were brown trout, Eastern brook trout and rainbow trout (see Table 3-1). In addition to the stocking performed by the NHF&GD, the Great Bay Chapter of Trout Unlimited has also stocked trout in the lower Lamprey, in the reach from Wiswall Dam to Packers Falls (Smith, pers. comm.).

The Lamprey River is a popular river for recreational fishing, as it is easily accessible, and provides a variety of habitats. Popular areas for fishing in Durham include the ¾ mile stretch between Wiswall Dam and Packer's Falls, and in Lee, the stretch between the North and Little Rivers and the areas around the Cartland Road / Little River Bridge and the Lee Hook Road / Lamprey River Bridge. All of these areas are accessible from roads and these reaches can be fished by wading or from the shoreline.

Within the designated segment, the management goal is to sustain stocked fish during the fishing season. In addition, to manage the fishing resource, within the designated segment, the NHF&GD has established special fishing rules. These rules are in effect for the section between Wiswall Dam to the first railroad trestle downstream of Packers Falls. Under the Special Rules "there is no closed season for taking all species except salmon and smelt. From October 16 to the fourth Saturday in April all fish must be immediately released and only single hook artificial lures and flies shall be used; and , all hooks shall be barbless or have all barbs pinched. From the fourth Saturday in April to October 15 fish may be taken by all legal methods and the daily limit for brook trout shall be 5 fish or 5 pounds, whichever limit is reached first" (NHF&GD 2006).

Proposed Assessment Methods for Fishing

No methods for the assessment of fishing or the development of a fishing specific PISF are proposed. At a minimum, the goal relative to fishing is to have sufficient stream flows to sustain stocked fish during the fishing season. The actual assessment of PISFs for fish (and hence fishing) will be performed for aquatic fish life maintenance and enhancement, which is described in the following section.

Table 3-1. Fish Stocked in the Lamprey River in 2005.

Total Fish Stocked in Lamprey River – 2005				
Town	**Species**	**Age of Fish**	**Number of Fish**	**Lbs. of Fish**
Deerfield	BT	1+Yr	600	222
Deerfield	EBT	1+Yr	700	302
Deerfield	RT	1+Yr	600	604
Durham	BT	1+Yr	540	195
Durham	EBT	1+Yr	1,640	771
Durham	EBT	3+Yr	75	156
Durham	RT	1+Yr	560	557
Epping	BT	1+Yr	630	256
Epping	EBT	1+Yr	100	47
Epping	RT	1+Yr	700	715
Lee	BT	1+Yr	1,010	348
Lee	EBT	1+Yr	1,330	571
Lee	RT	1+Yr	180	178
Raymond	BT	1+Yr	600	243
Raymond	EBT	1+Yr	200	94
Raymond	RT	1+Yr	400	413

BT – Brown Trout EBT – Eastern Brook Trout RT – Rainbow Trout

3.1.3 Aquatic and Fish Life Maintenance and Enhancement

The assessment of aquatic and fish life maintenance and enhancement will be based upon the native fish community derived for the designated segment. Although the fish community presently includes both native and introduced species, only those existing resident native fish species and those native species (i.e. Common shiner) that have the potential to occur in the Lamprey River will be evaluated.

Resident Native Fish Community

NHDES, through fish collections, performed in August 2003, from various habitats using multiple sampling methods, has identified the resident fish community (Lamprey Baseline Fish Community or LBFC) for the Lamprey River. The results of these collections have been presented in the Lamprey River Baseline Fish Sampling Report (NHDES 2005; Table 3-2). A Lamprey Target Fish Community (TFC) will be developed based on the fish collection data obtained from the Lamprey River Baseline Fish Sampling and additional historical fisheries information. The determination of TFC will follow the standard procedure described by Bain and Meixler (2000), without including introduced species. The final composition of the TFC will be determined with help of state and federal fisheries experts. The TFC will create the basis for the determination of habitat structure necessary to support the native fish fauna and allow for a comparison with the existing habitat structure.

Flow dependent species from the TFC will be selected for PISF modeling. The existing habitat data base and literature will be used to establish habitat selection criteria for each of these species. The fish collection data obtained during Lamprey River Baseline Fish Sampling will be used for validation of habitat models. The fisheries data bases will be used to identify critical river ecosystem

Table 3-2. Summary of Lamprey Fish Assemblage (August 25-29, 2003) (NHDES 2005).

Fish Species		# of Individuals	Percent of Total Fish Captured	Number of Stations Found (n=43)	% of Stations Found
Common shiner	(FD)*	2140	33.9%	17	40%
Redbreast sunfish	(MHG)	948	15.0%	24	56%
Fallfish	RFS)	767	12.2%	24	56%
Pumpkinseed	(MHG)	377	6.0%	30	70%
Bluegill	(MHG)	358	5.7%	9	21%
Common white sucker	(FD)	324	5.1%	29	67%
American Eel	(MHG)	288	4.6%	26	60%
Longnose dace	(RFS)	287	4.6%	8	19%
Golden shiner	(MHG)	239	3.8%	17	40%
Smallmouth bass	(MHG)	128	2.0%	23	53%
Largemouth bass	(MHG)	95	1.51%	20	47%
Yellow perch	(MHG)	77	1.22%	18	42%
Bridle shiner	(MHG)	54	0.86%	5	12%
Yellow bullhead	(MHG)	51	0.81%	15	35%
Eastern chain pickerel	(MHG)	38	0.60%	17	40%
Creek chubsucker	(FS)	22	0.35%	10	23%
Alewife	(MHG)	21	0.33%	4	9%
Blacknose dace	(FS)	19	0.30%	2	5%
Black crappie	(MHG)	18	0.29%	3	7%
Rock bass	(MHG)	18	0.29%	1	2%
Atlantic Salmon	(FD)	13	0.21%	4	9%
Brown bullhead	(MHG)	11	0.17%	6	14%
Redfin pickerel	(MHG)	6	0.10%	4	9%
Brown trout	(FD)	3	0.048%	2	5%
Blueback herring	(FD)	2	0.032%	2	5%
Rainbow trout	(FD)	1	0.016%	1	2%
	Sum	**6305**	**100%**		

* Key to Habitat Classifications: FD=Fluvial Dependant; MHG=Macrohabitat Generalist; RFS=Regional Fluvial Specialist

processes for migratory and specific life stages of the river fauna. Subsequently, biological periods when migratory species and specific life stages of resident fauna are particularly dependent on appropriate flows will be determined.

The timing and duration of these bio-periods is determined using a literature based, life history analysis of the biological needs of the resident target species identified in the TFC, and the fluvial dependent, diadromous pulse species with potential to occur within the Lamprey River. Identifying critical bio-periods will allow us to recognize the corresponding flow regimes that are necessary to support the habitats required of these species during these times. This will be accomplished using a Lamprey River mean daily flow hydrograph (based on 71 years of record) to compare the identified bio-periods for the species of interest to the corresponding mean daily flows on the Lamprey River, as shown conceptually in Figure 3-1.

Figure 3-1. Initial bio-periods developed for the Lamprey River plotted over 71-year daily mean hydrograph.

Further, a list of fisheries management goals based on local, state, and federal management stakeholder values will be developed. Analyzing these goals and the key ecosystem processes driving the shape of the fish community, we will identify manageable components of the flow regime critical to achieving these goals and supporting the TFC. The purpose is to meet user goals and the biological needs of the TFC. An important by-product of this process will be the identification of conflicting or incompatible user goals and gaps in management planning for the river ecosystem.

Native Fish Species

Based on our observations and the data available from the NHDES (2005), the native fish species in the designated segment of the Lamprey River include alewife, American eel, American shad, Atlantic salmon, banded sunfish, blacknose dace, blueback herring, bridle shiner, brown bullhead, common shiner, common white sucker, creek chubsucker, eastern chain pickerel, fallfish, golden shiner, longnose dace, pumpkinseed, redbreast sunfish, redfin pickerel, sea lamprey, swamp darter, yellow perch, white perch.

Introduced Fish Species

Based on the data available from the NHDES (2005), introduced fish species present in the designated segment of the Lamprey River include bluegill, black crappie, brown trout, largemouth bass, rock bass, smallmouth bass, yellow bullhead, and rainbow trout. Although these species are not native, they have been introduced and are part of the aquatic community. The rainbow and brown trout are currently stocked by the New Hampshire Fish and Game Department to support a recreational coldwater fishery (Table 3-1).

3.1.4 Fish and Macroinvertebrate Habitat

Fish use stream habitats for spawning, feeding, nursing grounds, migration, and shelter, but most single habitats do not meet all of the needs of a fish. Fish change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its characteristics and functions, are important to a diversity of fish species, and their changing life history needs. Descriptions of fish species, their characteristics, and habitats may be found in Appendix A.

Fish Life-stage Habitats

Freshwater portions of the Lamprey River, including the designated segment, provide spawning and rearing habitat for resident and diadromous fish. According to the Lamprey River Management Plan (LRAC 2006), "The presence of and potential for additional runs of river herring, American shad, and Atlantic salmon make (the Lamprey River) the state's most significant river for all species of anadromous fish." The river contains considerable amounts of suitable Atlantic salmon nursery habitat (gravelly, sloping bottoms, with cool, oxygenated water) and efforts to restore this species to the river are currently underway. The fish ladder at Macallen Dam in Newmarket passes alewife, blueback herring, American shad, sea lamprey, and American eels. This allows diadromous fish access to existing habitat from Great Bay upstream to Wiswall Dam. Potential habitat exists above Wiswall Dam pending the construction of a fish passage facility. Bathymetric studies of the geologic formations at Wiswall Dam reveal a low incline rock and ledge structure (ACOE 2005). Therefore, it is believed that all of the diadromous fish species mentioned above (alewife, blueback herring, American shad, sea lamprey, Atlantic salmon, and American eel) had the potential to access spawning habitat at least as far upstream as Wadleigh Falls prior to the construction of the Wiswall Dam (Patterson 2005). As a result of this belief, and in an effort to restore access to former spawning habitat for these fish, plans are currently underway to build a nature-like, bypass channel fishway (NHF&GD 2005).

Macroinvertebrates

Many macroinvertebrates such as freshwater mussels, mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera) (EPT Taxa) and Odonates (dragonflies and damselflies) are dependent upon good water quality. Their presence can be an indicator of a healthy water body. As with most macroinvertebrates, not much is presently known about their microhabitat needs. It is likely that habitat used by these animals can differ from fish habitat. Therefore, including macroinvertebrates in the investigation will help to represent a broader range of biodiversity for making instream flow recommendations. This is logical from a conservation viewpoint, because both of these groups contain state and federally listed endangered species. Efforts to conserve habitat for common species may generally result in protection for imperiled species.

The following sections provide an introduction to freshwater mussels and insects relative to this project, while more specific information is included in Appendix A.

Mussels

The freshwater mussel (Bivalvia: Unionidae) assemblage in North America is one of the most diverse known, and also one of the most imperiled (Vaughn and Hakenkamp 2001; Strayer et al. 2004). Essentially sedentary or slow-moving animals, the river species are particularly vulnerable to fluctuations in water level and current. Although many features of the watershed landscape have been shown to affect the composition of mussel communities (Arbuckle and Downing 2002), impoundment of rivers and the resultant effects on flow regime and host fish species are considered the primary factors in the decline of many North American freshwater mussel communities (Vaughn and Taylor 1999; Parmalee and Polhemus 2004; McGregor and Garner 2004). Flow stability and substrate composition determine where mussels are found in a water body (McRae et al. 2004), and patchiness in distribution may be due to the use of flow refuges (Strayer 1999). Flow velocities that are too high can negatively affect mussels by causing reduced juvenile recruitment (Hardison and Layzer 2001). Conversely, flow velocities that are too low can result in sedimentation, changing the substrate type and making it unsuitable for a given mussel species. Flow management is an important factor in maintaining a healthy mussel community in riverine systems (Brunke et al. 2001).

Mussels are important in bodies of water as they maintain clean water by filtering algae and plankton, and are a source of food for many species of wildlife such as raccoons and muskrats. Seven species of mussels have been reported from the Lamprey River, the brook floater, triangle floater, creeper, Eastern lampmussel, Eastern floater, Eastern elliptio, and alewife floater (Wicklow 2005). Several additional species may be present, including the Eastern pearlshell, Eastern pondmussel, tidewater mucket, and yellow lampmussel.

The life cycle of mussels starts with the release of sperm into the water by a male mussel, which a female mussel collects when siphoning water for food. The sperm is retained upon her gills, where her eggs are fertilized and develop in a few weeks. The next generation of mussels emerges after this time-period as glochidia, the larvae of mussels. Fish play a host, as the glochidia attach to the gills of specific fish species. Some of the identified hosts include tesselated darters, blacknose dace, golden shiner, longnose dace, margined madtom, pumpkinseed, slimy sculpin and yellow perch. These host species of fish are attracted to the area through a chemical emission, or lure, which the female mussel produces. Using the host fish as a means of dispersal, the glochidia are capable of reaching new locations in which they can colonize populations. These mussel larvae disengage from the host fish after a period of time, and if they relocate onto suitable substrate where local water velocities and flow regime of the river are suitable, the immature mussel will develop, and continue the life cycle.

Most freshwater mussels live burrowed in sand and gravel substrates, often occurring in the shallows of rivers and streams. Many species prefer a habitat that offers highly oxygenated water and moderate current. Only a few species have adapted to life in reservoirs, lakes or pools (lacustrine zones). Most freshwater mussels are dependent upon fluvial conditions and have an important role in river ecology. Factors such as water pollution, siltation, and impoundments have been known to cause declines in mussel populations. Well-established, diverse mussel colonies generally indicate a healthy aquatic environment.

Insects

There are a variety of insects that are dependant upon river systems for habitat and breeding grounds. In this study, effort will be focused on dragonflies and damselflies (order Odonata). Other taxa will be archived for future evaluation.

Odonates are good indicators of water quality and easily identifiable by their shed exoskeletons or adult forms. If river habitat is impacted by sedimentation or an increase or decrease in stream flow, these insects are affected. The flow needs of these macroinvertebrates vary throughout the season, as they emerge from rivers from the spring to early fall (Lenz 1997).

As of January 2003, there were 108 species of dragonflies and 44 species of damselflies reported in the State of New Hampshire (NH Odonates Club 2004). Many species of dragonflies and damselflies have been recorded throughout Strafford County, and within the Lamprey River watershed, but the only dragonfly species listed as endangered is the ringed boghaunter (*Williamsonia linteri*). This species requires acidic fen or sphagnum moss bog habitats that have been identified within the Lamprey River watershed. Such bog habitat exists at Durham Point Sedge Meadow Preserve, Durham, that currently supports ringed boghaunters (TNC 2004). Other bog habitats, suitable for ringed boghaunters, exist within the watershed in the Nottingham region and at Spruce Hole Bog, Durham. In general, Odonate larvae occur around most types of fresh water, but are uncommon in fast moving sections of streams. Both dragonflies and damselflies seem to thrive near sluggish waters. As a family, Odonates require a diversity of aquatic substrates upon which their eggs are laid. Several characteristics of these organisms make them useful indicators of water quality: many are sensitive to physical and chemical changes in their habitat, many live in the water for periods exceeding one year, and, they cannot easily escape pollution as some fish can. Odonata are easily collected in many streams and rivers for research.

Proposed Assessment Methods for Instream Resources

For this study, instream resources are considered to include fish and macroinvertebrates and their associated habitats. In the evaluation of the instream flows necessary to protect these instream resources the Natural Flow Paradigm (NFP) (Poff et al. 1997) will be adopted as an organizing framework for developing PISF recommendations for the Lamprey River.

Within this concept the naturally occurring flow patterns are considered a key component of physical habitat template that produces specific biological responses, which are reflected in aquatic community structure and function (Poff & Ward 1990, Townsend & Hildrew 1994). The maintenance of natural flow patterns is necessary for sustainability of aquatic ecosystems. As mentioned in the introduction to this report (Section 1.0) flow regimes can be described in terms of five general attributes that characterize temporal patterns and invoke conceptual linkages to other ecological variables. These include flow *magnitude, timing, frequency and duration and the rate of change. Magnitude* is used to distinguish between low, normal, and high flow conditions. The predictability of the *timing* of high and low flow events may select for or against various life history characteristics of resident biota. *Frequency* and *duration* interact to define disturbance intensity and the *rate of change* in flow conditions interacts with organism mobility and availability of refuge from intolerable physical conditions to further characterize the intensity and consequences of disturbance.

The NFP is not a method, but rather, it is an over-arching philosophy that will be used to assess and prioritize efforts to understand the instream flow needs of various IPUOCR entities. NFP framework results in a description of the PISF that allows for droughts on a natural regularity, but protects the river by limiting the duration and frequency of these low flow events. Low flows can occur for the natural durations and frequency without restrictions on withdrawals. By describing variable flow conditions, NFP is protective of the ecosystem without over regulating withdrawals. It will also be used to devise new or select from existing methods needed to answer questions when placed in a water management framework. Methods to be used in the evaluation of PISFs for instream resources include a statistical analysis of historical flows to characterize the existing flow regime and an instream flow assessment using a meso-scale habitat approach.

Indicators of Hydrologic Alteration

Statistical tools such as the Indicators of Hydrologic Alteration (IHA) (Richter et al. 1996) and related indices like those used by Poff and Ward (1989) can be used to characterize patterns of stream flow variation over time. Stream ecologists are challenged to choose appropriate and relevant indices from the available suite of indices. Olden and Poff's (2003) comprehensive review of currently available hydrologic indices for characterizing streamflow regimes and their recommendation of non-redundant indices based on stream types will be used to guide index selection in this study.

A preliminary analysis of historical flows for the Lamprey River has been performed using the IHA and the results are compared with the three low flow IHA statistics (7-day low, 30-day low and low pulse duration) developed by the Massachusetts Water Resource Commission (WRC) for Massachusetts basins (Abele 2004) (Table 3-3). These results indicate that the overall Basin Stress Index (BSI) for the Lamprey River is high. The duration of high and low pulses in the Lamprey show a level of persistence indicative of flow regulation, water withdrawals or generally low contributions from groundwater.

Table 3-3. IHA statistics for the Lamprey River for the Period of 1934 to 1976 and Their Comparison with Calculated Stress Thresholds.

IHA	Median Statistics for 1934-1976		MA Stress Thresholds	
	Lamprey	Stress[1]	Low-Med	Med-High
7-day low flow (cfsm)	0.06	High	0.22	0.09
30-day low flow (cfsm)	0.10	High	0.30	0.16
Low pulse duration (days)	18.50	High	6.80	10.90
Overall basin stress index		**High**		
7-day high flow (cfsm)	8.36	NA	NE	NE
30-day high flow (cfsm)	5.11	NA	NE	NE
High pulse duration (days)	12.40	NA	NE	NE

1 – Massachusetts derived stress thresholds (Abele 2004)
NA – Not available
NE – None established

A comparison of historical streamflow data (1935-1966) to more recent flows (1967-1990) showed that, while the duration of flooding events has remained relatively the same over the period of interest, the duration of drought periods has increased in the Lamprey. This increase in conjunction with the high IHA indicator values shows that the Lamprey basin is highly stressed (altered flow regime). This is likely due to human pressures resulting in increased water demand during annual low flow periods.

Due to geographic variation in IPUOCR entities and existing water use patterns, methods will likely be needed to estimate stream flow records for un-gauged locations of interest in the watershed (see Richter et al. 1998). There could well be a need to compare flow regime attributes to those of a nearby reference stream, or between two time periods that bracket a significant change in water use within the basin. Consequences of such changes, or of projected future water use scenarios, will then be evaluated with other methods specific to the nature of each IPUOCR entity. These could be grouped into classes or habitat guilds, reducing the number of methods ultimately required to address all pertinent issues (examples of such methods are given later in this section).

Instream Flow Assessment

Because analyzing all components of the Lamprey Rivers' aquatic ecosystem would be an enormous and overwhelming task, this study will focus on fish and freshwater mussels as a primary indicator of ecological integrity. Fish and mussels are the primary animals of widest interest to the public in the river, and freshwater mussels are the most likely invertebrate group to be rare or endangered. Thus both are important components of any PISF recommendation.

The approach to be used in the assessment of these instream resources is the meso-scale habitat simulation (or MesoHABSIM) method (Parasiewicz 2001). MesoHABSIM (Parasiewicz 2001) is an experimental habitat assessment technique being developed in the northeastern United States which addresses the requirements of watershed-scale management of running waters. MesoHABSIM is an improvement of existing physical habitat simulation models, such as PHABSIM (Bovee 1982), where PHABSIM was originally developed for reach scale applications. MesoHABSIM modifies the data acquisition technique and analytical approach of earlier physical habitat models by changing the scale of resolution from micro- to meso-scales. Hydro-morphological units (e.g., riffles, pools and runs) as well as associated hydrologic and cover characteristics are used to describe mesohabitats. When applying the MesoHABSIM survey approach, mesohabitats are mapped at different flows along extensive sections of a river. The suitability of each mesohabitat for a fish species is assessed using fishing surveys. These survey data are subsequently analyzed using multivariate statistics. The variation in cumulative area of suitable habitat is a measure of environmental quality associated with alterations in flow and channel structure (Figure 3-2).

The underlying philosophy of MesoHABSIM is the recognition that fauna react to the environment at different scales related to the size and mobility of the species (Nestler et al. in press) as well as the time of use. MesoHABSIM defines the units of meso-scale (mesohabitats) as areas where an animal can be observed for a significant portion of their diurnal routine and it roughly corresponds with the concept of functional habitat (Harper et al. 1995). The natural mobility of fish observation at the meso-scale is less affected by coincidence than at the micro-scale and can be expected to provide relatively meaningful clues about the animal's selection of living conditions (Hardy & Aadley 2001). As shown by several studies (Aadland 1993, Bain & Knight 1996, Lobb & Orth 1991), hydromorphologic units (HMU's) and mesohabitats commonly correspond in size and location, at least for adult resident fish. MesoHABSIM takes advantage of this non-coincidental relationship and defines HMU's as primary units of scale. Because of a coarser scale, HMU's are much more easily described and measured than micro-habitats and therefore allow for rapid surveys of large river sections, reducing the amount of extrapolation and associated errors.

Instream Habitat Assessment and Mapping

The approach of this study is to develop criteria for a flow regime that protects aquatic and riparian life within the designated segment and, by extension, throughout the watershed. Thorough understanding of ecological flow needs will be the basis for the development of the Water

Figure 3-2. The habitat survey delineates hydromorphologic units and their physical attributes (top left). The fish survey is combined with this to identify key habitat attributes affecting fish (top right). The model calculates the probability of fish presence in each habitat and delineates areas of suitable and unsuitable habitat.

Management Plan (WMP). For this project, methods need to be applied at two different scales. The flow requirements of the designated segment need to be assessed at the river scale and the Water Management Planning Area (WMPA) upstream of the designated segment needs to be analyzed at the watershed scale. The need for the second model is given not only by flow management opportunities upstream of the designated segment, but also by a necessity to protect this portion of the watershed from unintended damage, for example, by reduced flows. The primary approach is to classify the streams in the watershed based on their ecological status and potential vulnerability to change.

Because the developments in the WMPA, such as increased impervious area and higher flow fluctuations, could have a strong influence on conditions in the designated segment, the conditions and potential impact sources upstream of it will be assessed. If determined necessary, more generic techniques of impact assessment will be used to identify the natural flow pattern in delineated sub-watersheds. This will require the collection of continuous and concurrent flow data at critical locations in each sub-watershed. Subsequently the IHA will be calculated to identify limits for suggested flow modification. Available remotely sensed data (satellite and aerial photographs) will be reviewed to study all of the sub-watersheds of the Lamprey River to classify the land use and percent imperviousness.

The meso-scale physical habitat approach links a small number of hydraulic variables (depth, velocity) and habitat variables (cover, substrate) to model suitability for target biota (habitat suitability criteria) and can be used to establish specific flow criteria when a specific site or sites have high importance to an IPUOCR. This method will be applied to all free flowing sections of the Lamprey River using high resolution, multispectral-aerial photography as a primary tool of data collection. These data will be accompanied by ground-truthing surveys, which will help to calibrate and validate the image recognition software results for habitat delineation.

Mesohabitat mapping of the designated segment will be performed using high-resolution aerial photographs at four flows in the range between 0.15 cfsm and 2 cfsm as the primary approach to describing flow-related habitat changes (Figure 3-3). During each flight a 3,000 ft wide corridor along the river will be captured from an elevation of 4,000 ft providing a final horizontal resolution of 5 inches.

To increase the efficiency of the large scale field surveys of the habitat characteristics the software tools developed by Pal et. al (2001) for automating the classification of pixels in aerial imagery into categories relevant to habitat will be used. These tools use a hierarchical, tree-structured Bayesian network probability model to integrate pixel color and intensity or texture (or wavelet) features in color aerial photography. This method has been used in a software system for classifying pixels and larger regions into features relevant to landscape ecology and hydrologic modeling. In a related model (Pal et al, 2001), a Markov Random Field (MRF) was used to classify black and white aerial imagery. Figure 3-4 illustrates iterations of the MRF based algorithm. This study will adapt and build upon these approaches for automated recognition of habitat features and hydraulic patterns on the water surface.

In addition, a reconnaissance level survey of the impoundments will be performed. The purpose of this survey is to identify the species that utilize impoundment habitats and roughly estimate the value of this habitat for the aquatic community. This will be accomplished by utilizing SCUBA divers trained in the recognition of fish and freshwater mussel species who will also roughly map the underwater topography. Figure 3-5 shows an example of the result of this approach as it was applied to the Souhegan River. This information, while somewhat crude, provides a useful addition to the study that could not be obtained through wading or electrofishing surveys.

Instream Habitat Modeling

To create a habitat model, it is necessary to have two types of data; the characteristics of the stream and the biological response functions (habitat use criteria). These allow for the evaluation of hydro-morphology in terms of habitat suitably. Based on prior experience working on similar instream survey projects located in the Northeast, a well developed habitat database on the adult and early life stages of resident native fish for regional river systems (including the Souhegan River, Eightmile River, Pomperaug River, Fenton River, Stony Clove Creek) is available and will be used in this study. These data allow for the development of habitat use criteria for the majority of fish species identified in this IPUOCR report. These criteria will be used as the basis for the evaluation of habitat quality for these species in the areas mapped with the MesoHABSIM technique.

Figure 3-3. Schematic of mapping procedure planned for the Lamprey River.

Figure 3-4. (left to right) 1. Black and white aerial imagery, 2. An initial segmentation, 3. Iterations of the algorithm 4. A "perfect" hand generated segmentation.

Figure 3-5. Results of scuba investigation of one impoundment on the Souhegan River.

Subsequent to the development of the habitat use criteria, the instream habitat modeling proposed for this study will proceed following the approach previously developed for the Quinebaug and Souhegan River studies (Parasiewicz 2005) and include the following steps:

- Selection of resident fish species
- Identification of bio-periods
- Analysis of habitat conditions and flow levels
- Recommendations of seasonal flow regimes

The resident fish species to be modeled will be selected from the target fish community (TFC) that we will develop for Lamprey River (Bain and Meixler 2001). The TFC will be compared with the Baseline Fish Community developed by NHDES (NHDES 2005) and the species or species groups that have highest flow needs in a particular season (e.g. spawning salmon in the fall) will be used as indicators for PISF needs and for habitat modeling. For species that are not included in the regional database, habitat selection criteria will be developed using literature values.

Timing is one component of the NFP. The flow requirements of the fauna and of the flow regime itself vary through the course of a calendar year. When attempting to prescribe flows in a river, it is necessary to take into consideration these flow and habitat fluctuations. To do this, the hydrograph for the Lamprey River, over a calendar year, will be partitioned into bio-periods, where these bio-periods reflect the special or critical times that a particular fauna or life stage may be particularly limited due to a lack in habitat.

The timing and duration of bio-periods are primarily based on upon species present and life history information found in the literature. Using a simulated hydrograph as a guide, the bio-periods of interest will be lengthened or shortened to have the biological requirements coincide with a consistent flow pattern, which is often associated with a particular life history requirement such as high spring flows for spawning.

If biological data are unavailable or too sparse, the bio-periods developed will be based solely on consistent patterns (either relatively stable or relatively dynamic) in the simulated hydrograph. For example, the termination of the resident fish species spawning period was adjusted slightly from general literature information to coincide with the inflection point of the receding limb of the hydrograph – the point where it is likely that the target fauna would cease spawning.

Spring/fall spawning and low flow summer survival/rearing and growth conditions will be considered as the primary biological periods of importance. Over-winter survival and the spring flood/storage periods are the other bio-periods that will be evaluated solely by the simulated hydrograph. The spawning periods of the top five target resident species and those of the two selected locally extirpated anadromous species (Atlantic salmon and American shad) will be obtained from published literature.

Using habitat rating curves, in conjunction with flow time series for each river segment or IPUOCR site, a time series of baseline habitat conditions will be created and then analyzed for flow levels critical to the protected use. Continuous under threshold habitat duration curves (CUT curves) will be applied using the technique described by Capra et al. (1995). CUT curves describe the durations when habitat needs are met based on the flow variations in a bioperiods daily hydrograph and the habitat available at those flows. The process is illustrated in Figure 3-6. Using this method we will identify up to four habitat levels that correspond with different flow protection thresholds. These habitat levels divide the flow regime characteristics along a gradient of potential impact and are named *extreme, rare, critical, and common*.

A set of CUT curves for a bio-period will be generated by analyzing negative run-time length (i.e. continuous durations of under threshold) characteristics of habitat time series (or habitographs). Habitographs will be computed by applying flow/habitat rating curves developed for restored river conditions to a given bioperiod's flow time series. The magnitude and duration of habitat run length characteristics relative to a series of thresholds is plotted as habitat duration curves on one chart. Thresholds are initially selected on an iterative basis to refine the evaluation to target threshold regions. These target threshold regions demonstrate characteristics where trends depicting common and uncommon occurrences can be discerned.

For low-flow conditions, four habitat levels that correspond with different levels of flow thresholds following the theory of physical habitat templates (Poff and Ward 1990, Townsend and Hildrew 1994) will be identified as: *extreme, rare, critical, and common*. To define the *extreme* (which is the lowest habitat level allowable), the lowest non-zero habitat level that occurred in the pre-development daily streamflow time series will be selected. To define the other three levels, they will be interpreted from the shape of the CUT curves. An example of CUT curves developed for the Quinebaug River is shown in Figure 3-7.

In Figure 3-7, the selected increment between habitat levels is 2% of the channel's wetted area. The area under the curves indicates the change in frequency of events associated with a habitat increase to

Figure 3-6. CUT curves from habitat time series (source: Capra et al., 1995).

Figure 3-7. Continuous Under Threshold duration (CUT) curves representing percentages of available habitat area for adult resident fish in the Quinebaug River during the summer season (Parasiewicz 2005).

the next level. The curve spacing increases constantly but in non-uniform increments, thereby displaying a sudden shift in frequency. For this study it is assumed that thresholds defining the four habitat levels are associated with such a significant increase of spacing between the CUT curves.

For the Quinebaug River (Parasiewicz 2005), it was observed that for *rare* levels, which are exceeded very frequently and over long periods of time, the curves are steep and located in the lower left-hand corner of the graph. The curve representing the highest level of this group of curves was chosen as a *rare* habitat level. The first curve that stands out is identified as the *critical* (yellow curve) as it marks the lowest of events more common than *rare* (red curve). After exceeding the *critical* level, the lines begin to space out more. The next significant increase in the distances between the CUT-curves marks a first *common* (green curve) event.

For each of these thresholds, significant changes in the shape of the curves will be identified as to define the shortest common, longest common, and catastrophic durations. The shortest common duration, the lowest inflection point on the CUT curve, is used to determine the duration of a relief flow pulse length. The longest common and catastrophic durations describe two categories: persistent or catastrophic. Persistent duration, the longest common duration, at the uppermost inflection point of the CUT curve, defines the maximum durations for which the habitat can fall under the threshold or the duration between relief successive pulses. The catastrophic duration is that, which if exceeded (e.g. for lack of water), would require additional mitigation actions (reduction in withdrawals, flow augmentation, etc.) in order to recover the fauna.

The result of this analysis will be recommendations for bioperiod habitat flow regimes consisting of allowable habitat quantity together with duration and frequencies of flow events with habitat under specific thresholds. In addition, the amount of water necessary to fulfill the above criteria will be defined for every bioperiod. These results can then be used to develop a concept for the application of these criteria by introducing dynamic flow management rules. This will include flows that trigger protective actions, allowable durations of these flows, together with duration and magnitude of protective flow pulses. For each flow scenario the change in wetland habitats as well as potential impact on stream miles in the WMPA upstream of the designated segment will be analyzed. The above rules will be accompanied by boundary conditions (flow values) for protecting wetlands and upstream areas.

3.1.5 Natural Communities and Wildlife Habitat

Many of the wetland, floodplain and river channel plant communities along the Lamprey River are flow dependent habitats for a variety of flow dependent and non-flow dependent wildlife. Wetland types along the Lamprey River include forested floodplain, oxbow marshes, and shrub and forested swamps at the mouths of tributary streams and riparian margins. The plant community types associated with important wildlife habitats have been classified by the NHNHB, and are described below.

Lower Floodplain Forest

Lower floodplain forests are typically 3 to 5 feet above summer river levels and 1 to 2 feet above average spring high water. These forests probably flood annually during peak flood flows. Dominant tree canopy species include red maple (*Acer rubrum*), red oak (*Quercus rubra*), American elm (*Ulmus Americana*), black cherry (*Prunus serotina*), and shagbark hickory (*Carya ovata*).

Musclewood (*Carpinus caroliniana*) is a common understory tree, and shrubs, including several species of viburnum may be common. The ground cover is a mixture of ferns, sedges and other forbs. Such forests were observed above Wadleigh Falls and in small, scattered locations below this. Silver maple (*Acer saccharinum*) is found along the river occasionally in narrow bands or with other lower floodplain species. These trees are generally found about 1 to 2 feet below the other lower floodplain forests, and were most common below Packers Falls, particularly near Moat Island.

Higher Floodplain Forest

Higher floodplain forests, positioned approximately 1 to 3 feet higher than lower floodplain forests, generally flood in 5-100 year cycles. These forests are reminiscent of mesic mixed forests, often including hemlock (*Tsuga canadensis*), but also support many lower floodplain species. These forests are often present adjacent to the lower floodplains, either further back from the Lamprey River or on naturally higher banks along the river edge.

Alluvial Red Maple Swamp

Red maple swamps on organic soils develop within old oxbows, meander scrolls or tributary basins protected from swift water and scour. These swamps are similar to other red maple swamps in basins not located in the floodplain of the Lamprey River, and are sometimes associated with emergent and shrub swamps.

Oxbow and Backwater Shrub Swamps, Marshes and Ponds

These open canopy communities are vegetated with shrubs, emergent marsh plants or submersed and floating leaved plants, depending on depth. Often they are found in a mosaic pattern with other floodplain wetlands. They are always influenced by the flood regime of the river, though some may be hydrologically isolated at low water. Beaver dams or man-made dams retain water in some of these oxbows and backwaters. Notable backwater and oxbow marshes were observed above Wiswall Dam, below Packers Falls, and around Moat Island. Numerous small fish, painted turtles (*Chrysemys p. picta*), and green frogs (*Rana clamitans melanota*) were observed in these marshes. Changes in river water levels would affect primarily those wetlands with direct and unrestricted surface water connections to the river. The magnitude of the impact depends, in part, on the elevation of the marsh relative to the river channel, the constriction of the surface water connection, and the frequency, regularity and duration of flow changes.

Floodplain Vernal Pool

Shaded oxbow ponds on the forested floodplain typically have sparse vegetation, but can have similar hydrology to open oxbow marshes and ponds. Some of these function as vernal pools, important breeding areas amphibians and invertebrates, and feeding areas for many wildlife species. Carroll (1994) noted several in the floodplain above Lee Hook Road.

Mesic-Wet High Energy Riverbank

This classification includes a variety of herbaceous plant associations in seasonally to semi-permanently flooded portions of the river channel. Species richness is often high, as plants may be emergent, amphibious or moist site species. The substrate may be very fine, or coarse, including alluvial sand or cobble bars and banks. An example is the alluvial bar just downstream of the Lee

Hook Road in Newmarket. Common plants in this habitat type may include cardinal flower (*Lobelia cardinalis*), water purslane (*Ludwigia palustris*), sensitive fern (*Onoclea sensibilis*) and false nettle (*Boehmeria cylindrica*).

River Rapids

Plant communities adapted to semi-permanently to permanently flooded conditions at high energy sites are present at Wadleigh and Packers Falls and the rapids near Lee Hook Road. Riverweed (*Podostemum ceratophyllum*), white water crowfoot (*Ranunculus tricophyllus*) and knotty pondweed (*Potamogeton nodosus*) are plants typical of rapids in the Lamprey River as observed by Sperduto and Crow (1994) at several of these locations. Numerous other species of plants may appear as water levels drop through the growing season.

Wildlife Habitat

Several floodplain wetland complexes representing combinations of the above plant community types within the study area were noted by various investigators for their habitat value, including:

- An area just north of Glenmere Village, noted for excellent bird habitat; vernal pools; emergent, forested and shrub wetlands; beaver dams; musk, painted, snapping turtles and potentially other turtle species;
- The Tuttle Swamp, with several floodplain and wetland cover types, including an outstanding Swamp White Oak (*Quercus bicolor*) Floodplain Forest and a rare plant; and
- A floodplain/wetland complex east of Lee Hook Road with potentially critical habitat for turtles, waterfowl, beaver etc.

Habitats with a direct hydrological connection (groundwater or surface water) to the river at some time during the growing season are potentially susceptible to prolonged changes in flow. Prolonged flooding and/or prolonged low water during the growing season both alter plant communities and microhabitats for plants, fish and wildlife. Major changes in winter flows could expose wintering aquatic animals to ice, scour, desiccation or dislodgement.

Wildlife dependent on these floodplains and wetlands may also be flow dependent. Loss of water in critical microhabitats during critical life stages can result in freezing or desiccation of water dependent animals. Examples include breeding amphibians that require ponded water for several months for aquatic egg and larval stages and turtles overwintering and feeding in the river channel. Flow dependent wildlife species observed informally from the Lamprey River corridor include:

- Amphibians - spring peeper, gray treefrog, bullfrog, green frog, wood frog, northern leopard frog, pickerel frog, American toad, Jefferson, spotted, and northern two-lined salamanders; red-spotted newt (which none are considered species of concern).
- Turtles - spotted, Blanding's, snapping, wood, painted, and musk (of which only the Blanding's, wood and spotted turtles are considered to be species of concern, Table 2-1).

Many other wildlife species may be indirectly flow dependent as they rely on flow dependent food sources. Examples include American black duck, black-crowned night heron, kingfisher, northern water snake, and ribbon snake. Bats and semi-aquatic mammals, such as mink, muskrat, otter and beaver may are also indirectly flow dependent through dependence on aquatic food sources.

Changes in river water levels would affect primarily those wetlands with direct and unrestricted surface water connections to the river. The magnitude of the impact would depend, in part, on the elevation of the marsh relative to the river channel, the constriction of the surface water connection, and the frequency, regularity and duration of any flow changes.

Proposed Assessment Method for Natural Communities and Wildlife Habitat

Several methods for determining flow requirements for riparian and floodplain communities and their associated fauna were considered for this project, including the Floodplain Transect and Wetland Photogrammetry Models described in our proposal to NHDES for this project. During the IPUOCR field reconnaissance, significant tree canopy was observed over the edges of the Lamprey River, backwater and oxbow marshes, and adjacent floodplain. This cover would obscure ground and water surfaces in aerial photographs taken during the growing season (May to October), when the likelihood of low flows is greatest. Additionally, large portions of the riverbank are populated by coniferous trees which would obscure the riparian zone throughout the year. It was also apparent that some of the natural communities of interest appear in narrow zones that will be difficult to discern on the scale of aerial photos. For this reason, this study will rely primarily on the information that can be collected through the Floodplain Transect Model (FTM), supplemented by aerial photographs collected as a part of the instream evaluation, where possible. At sites where air photointerpretation is possible, a comparison between aerial methods of evaluating cover and the transect method will be provided.

Floodplain Transect Model

Determination of minimum flow requirements for wetland, floodplain, and channel habitats and their associated flora and fauna will involve transect surveys across the river floodplain and channel, including selected backwater marshes, oxbows, vernal pools, etc. The expected change in plant community boundaries associated with water level changes at each topographic position is identified on the transect elevation model and transferred to a baseline cover type map developed from aerial photographs. For modeled flow scenarios the change in habitat suitability area will be calculated for a given segment of the river and extrapolated to other relevant reaches. The relative loss or gain of plant community types will serve as a measure of impact to the adapted flora and fauna. Where available, habitat suitability data will be integrated into the assessment. The initial steps involved with the FTM are as follows:

- Conduct a topographic survey of floodplain, wetland and adjacent river channel along transects, including the lowest point of connection with the river channel and deepest point of marsh;
- Document the elevation of water recorded simultaneously in wetland and river at seasonal low flow (or as determined by historical data), average and high flows. An attempt will be made to coordinate these evaluations with the evaluation of aquatic habitat and fauna.
- Use a stage-discharge relationship and topography at each transect to determine profiles of water levels along each cross section at representative flows.
- Identify primary vegetation types (emergent, floating leaved or submergent) in the wetland plotted along the transects;

- Estimate the minimum flow required to maintain low flow surface water elevations of:
    - 0 (sediment surface) for emergents,
    - 6 inches for floating-leaved;
    - 12 inches for submergents.

A cover type map showing the distribution of habitats in the floodplain of the selected reach around each transect will be prepared, based on aerial photos, and will be used to relate habitat changes associated with each transect to the entire river segment. This methodology will be applied at three or four sites in the designated segment. The number of transects at each site will be determined in the field. These sites will be chosen to overlap with the range of flow dependent species wherever possible. Examples of the FTM and type of output from this effort are presented in Figures 3-8 – 3-12.

Though the analyses of flow effects on IPUOCRs may focus on particular transect locations, the floodplain habitats discussed are part of an integrated and shifting mosaic, changed by river processes and beaver activity, with each habitat type important in the overall landscape for any number of wildlife species at a particular season or life stage. Many wildlife species likely to use floodplain habitats may also need adjacent undeveloped uplands or hydrologically independent wetlands to sustain their populations.

3.1.6 RTE: Fish, Wildlife, Vegetation or Natural/Ecological Communities

Fish

The New Hampshire Fish and Game Department's recent Wildlife Action Plan (NHF&GD 2005) was reviewed to identify fish species of "greatest conservation concern". Much of the information regarding the habitats uses of these fish within the state of New Hampshire was obtained from this plan. The species listed were then compared to field fish sampling records conducted by the NHF&GD and the NHDES (2005) to determine those rare, threatened, and endangered or species of conservation concern currently or historically occurring within the designated study reach of the Lamprey River.

Diadromous Fish Species

The designated segment currently provides spawning habitat for diadromous fish species. Plans to construct a natural bypass channel at Wiswall Dam, within the study area, would provide access to 43 additional river miles of potential spawning habitat for these fish (ACOE 2005). The NHF&GD considers the Lamprey River one of the most important rivers in the state of New Hampshire for all anadromous fish species, due to its current runs and potential to support future runs, according to the Lamprey River Management Plan (2006). This assertion lends reason to consider the flow needs of the diadromous species within the designated study reach with high regard. The very nature of diadromy, requiring diadromous fish to migrate to and from stream habits to reproduce and successfully complete their life cycles (Gross 1987), make these fish especially dependent upon specific flow conditions during their respective annual migrations and spawning times (Zabel 2002).

These particular periods of time, or bio-periods, have been identified for the diadromous fish species of the Lamprey River and then compared to the corresponding mean flow values for the Lamprey River to identify the times and flows that are critically important to the reproductive success of these species within the river. Six species of diadromous fishes have the potential to occur within the

Figure 3-8. Layout of transects.

Figure 3-9. Transect habitat mapping.

Adapted from Scott Jackson, UMASS

Figure 3-10. Habitat under different flows.

Figure 3-11. Relative change between flow regimes.

Figure 3-12. Habitat suitability under different flows.

Lamprey River. Four of these species, alewife (*Alosa pseudoherangus*), Atlantic salmon (*Salmo salar*), American eel (*Anguilla rostrata*), and blueback herring (*Alosa aestivalis*), were sampled within the designated study area during Lamprey River baseline fish sampling in 2003 (NHDES 2005). These species will be evaluated using MesoHABSIM as described above.

Banded Sunfish (Enneacanthus obesus)

Banded sunfish, a species with limited distribution within the state of New Hampshire, prefer vegetated backwaters, impoundments, and areas of slow-moving water within lowland streams (Scarola 1987, Page and Burr 1991). David Carroll reported catching banded sunfish in turtle traps fished in the Lamprey River (Carroll 1996). The majority of all banded sunfish records are from the rapidly growing southeast part of New Hampshire (NHF&GD 2005). This species' specific habitat preferences and limited distribution to an area threatened by rapidly increasing populations, places a high value on the need for identifying and protecting their instream flow and habitat needs within the designated segment of the Lamprey River. This species may be evaluated using MesoHABSIM.

Bridle Shiner (Notropis bifrenatus)

The designated segment provides habitat for the bridle shiner (Cairns 2005). This fish species prefers sluggish mud bottomed pools of creeks and small to medium rivers, and are often found in areas of vegetation (Page and Burr 1991). Bridle shiner were collected at multiple stations within the designated study reach of the Lamprey River in 2003 during the Lamprey River Baseline Fish Sampling efforts (NHDES 2005). Bridle shiner are experiencing population declines throughout their entire range (Sabo 2000) and has been typically found in less than 1% of the samples collected from the Lamprey River. Within New Hampshire their distribution is almost entirely limited to the southeast portion of the state, an area experiencing rapid growth (NHF&GD 2005). Given the range-wide decline of this species and their limited distribution within New Hampshire, the flow needs of this species should be should be addressed to provide for the conservation of this species within the Lamprey River. This species will be evaluated using MesoHABSIM.

Brook Trout (Salvelinus fontinalis)

Brook trout are dependent upon flow conditions that are favorable to the specific water quality conditions required of this species: cold, clean, well-oxygenated water with flowing riffles and pool habitat. They are unable to survive in water temperatures that exceed 20° C for any extended period of time (Scarola 1987). Brook trout are believed to have been far more abundant in the waters of New Hampshire historically (Noon 2003), and are currently experiencing population declines locally (New Hampshire), regionally (New England), and throughout their entire range (TU 2004). The upper portions of the designated segment provide potential habitat for brook trout. This species may be evaluated using MesoHABSIM.

Redfin Pickerel (Esox Americanus)

Redfin pickerel prefer habitats very similar to the banded sunfish and bridle shiner and are primarily limited within the state of New Hampshire to the southeastern part of the state (NHF&GD 2005). They inhabit shallow backwater areas of lowland streams, and are associated with areas of dense vegetation, woody debris, and leaf litter. They are tolerant of acidic, brackish, and poorly oxygenated water conditions. Redfin pickerel are dependent upon annual flooding episodes for access to spawning locations in the shallow vegetated backwaters of lowland streams (Scarola 1987).

Redfin pickerel were sampled on the Lamprey River in multiple locations within the designated study reach, both above and below Wiswall Dam, during the Lamprey River Baseline Fish Sampling efforts (NHDES 2005). This species limited distribution, specific habitat requirements and dependence upon marginal wetland floodplains makes it a species of conservation concern within the state of New Hampshire. Its presence at multiple sites within the designated study reach of the Lamprey River may suggest favorable habitat and flow conditions and could lead to the identification of other suitable habitats for this rare species. Redfin pickerel will be evaluated using MesoHABSIM as described previously.

Swamp Darter (Etheostoma fusiforme)

The swamp darter prefers heavily vegetated, shallow areas of lakes, ponds, and streams (Scarola 1987). This species is not currently protected within the state of New Hampshire, and little research has been conducted regarding the distribution status or health of populations within the state (NHF&GD 2005). Populations of this species, in New Hampshire, seem to be limited to watersheds within the southeast portion of the state. The rapid development an increasing human population in this region may pose a threat to the habitats of this species. This threat of habitat loss, when combined with the fact that New Hampshire is on the northern cusp of this species known range and this species short life span (1-2 years), make the swamp darter vulnerable to local or even regional extirpation (NHF&GD 2005).

Two records of swamp darter exist from the Lamprey River in samples collected by the New Hampshire Fish and Game Department between 1983 and 1985 on the mainstem of the Lamprey River (LBFC 2005). There were no individuals of this species collected during extensive sampling efforts on the Lamprey River conducted in 2003 (NHDES 2005). This rare species, facing the threat of extirpation, should be evaluated to identify potential habitat existing within the designated study reach. It may be evaluated using MesoHABSIM.

Invertebrates

Brook Floater (*Alasmidonta varicose*)

The designated segment provides habitat for the brook floater; a state listed endangered mussel species. These mussels prefer areas of cobble/sand substrate with moderate current (Cairns 2005). Brook floaters are particularly sensitive to regulated flow regimes and face local extirpations, as a result of low population densities, under unfavorable high or low flow conditions. On the Lamprey River brook floaters are scattered in very low numbers and are extremely vulnerable to inadequate flow conditions (NHF&GD 2005). The threat of local extirpation of this species from the Lamprey River exists if supportive flow conditions are not maintained. This species will be evaluated using MesoHABSIM.

Wildlife

The New Hampshire Natural Heritage Bureau provided information regarding rare, threatened and endangered species, species of concern, and exemplary natural communities along the Lamprey River study corridor. Field investigations previously performed by botanists and wildlife specialists, in part for the Wild and Scenic study, were also consulted for additional information regarding RTE species and their habitats.

Blanding's Turtle (Emydoidea blandingii)

Blanding's turtles (special concern species) prefer permanent shallow dark waters of bogs, swamps, ponds and slow moving rivers and coves, and the adjacent vegetation. They require shallow water with soft mud bottoms, and frequently nest in plowed fields near wetlands (DeGraaf and Yamasaki 2001). Most Blanding's turtles have been observed upstream of the project area along the Lamprey River. Several properties within the study area are known to support Blanding's turtles, including some large wetland complexes, some of which also may support spotted turtles. Blanding's turtles typically require deeper water than spotted turtles, and do not seem to make sustained use of the river channel, but do use it at times, if only during long-term dispersal (Carroll 1998). There are additional potential habitats in the study area without confirmed Blanding's turtle populations.

As with spotted turtle habitat, reductions in flow that drain wetlands or expose the bottom of waterbodies for prolonged periods in winter and spring could cause stress or mortality of Blanding's turtles. Water bodies potentially supporting Blanding's turtle that are located within the floodplain of the Lamprey River will be assessed using the Floodplain Transect Method.

Wood Turtle (Clemmys insculpta)

The wood turtle, a species of concern in New Hampshire, has been observed and documented in several locations within the Lamprey River study area by David Carroll, an experienced ecologist. The wood turtle has been classified as flow dependent species due to its reliance on riverine habitats in spring and summer for feeding and cover, and also for overwintering. The wood turtle overwinters on the bottoms of streams and feeds both on land and in the water (Taylor 1993) eating aquatic and upland plants and animals. Instream and riparian cover are extremely important for wood turtles (Carroll 2000). Instream cover includes deadfalls and debris drifts and dams, and cobbles and boulders. Natural wetland shrub borders along the river with herb cover, vines and debris and detritus provide cover for hatchlings through adults. Wide undeveloped riparian areas are best. Such habitat has been observed along the Lamprey and several of the larger tributary streams (Carroll 2000). Most of the wood turtles observed during David Carroll's studies were located upstream of the study area. However, suitable habitat appears to exist within the project area, though angling and other human activity may limit suitability. Wood turtles nest in dry, sandy, upland openings, which must be safely accessible from the river, but nest sites are typically above the floodplain and not flow dependent.

While loss of riparian habitat due to development is probably the greatest threat to this species in the watershed, changes in flow that cause the loss of bordering wetland shrubs (higher than normal summer flows, or lower than normal early growing season flows for years) could adversely affect wood turtle preferred habitat, and reduce survival. Flow changes that increase bank heights permanently would also adversely affect turtle habitat. Low winter flows that occur after the start of hibernation could expose hibernating turtles to ice or scour could result in direct mortality. This species is reported to be intolerant of pollution (DeGraaf and Yamasaki 2001), and therefore also indirectly flow dependent.

The flow regime proposed under the WMP will be examined to insure that fall and winter water flows and fluctuations are protective of hibernating turtles. The likely overwintering habitat will be examined during the low flow and winter habitat transect surveys, and the minimum flows sufficient to keep those areas inundated will be determined. Evaluation of flow effects on bordering shrub swamp habitat will also be considered in evaluating wood turtle flow dependence.

Spotted Turtle (Clemmys guttata)

Spotted turtles prefer heavily vegetated wetlands surrounding small and shallow bodies of water, such as small streams, ponds, vernal pools, and swamps. In winter, spotted turtles hibernate in water under tree root wads in vernal pools, or in wetlands, or the muddy bottoms of shallow waterbodies. Spotted turtles may aestivate in adjacent upland forests during the dry summer months (DeGraaf and Yamasaki 2001). Potential habitat for spotted turtles appears to be present in forested floodplains with pools and swamps and oxbow marshes, and historical observations exist (Carroll 2000).

Reductions in flow that drain wetlands or expose the bottom of waterbodies for prolonged periods in winter and spring could cause stress or mortality of spotted turtles. As with Blanding's Turtles, application of the Floodplain Transect Method will address spotted turtle habitat in floodplain wetlands.

Osprey (Pandion haliaetus)

The Osprey is a State threatened bird of prey observed foraging over the Lamprey River during the September reconnaissance. Ospreys are known to nest in Great Bay and may forage up to 7 miles away (Vana-Miller 1987). Ospreys observed along the Lamprey River in summer could be transient individuals. Ospreys consume primarily fish from clear, unobstructed water bodies. They dive up to 3 feet into the water, and so are most likely to feed in the pools and reservoirs, not shallow riffle areas. Only changes in flow that eliminate pools, reduce fish abundance, increase turbidity, or increase aquatic plant cover are likely to affect ospreys. Flows that are protective of a healthy fish community will be protective of this species, so the MesoHABSIM model will be interpreted for osprey.

Bald Eagle (Haliaeetus leucocephalus)

Bald eagles are a federally threatened, state endangered species re-colonizing their historic range. Eagles nested in New Hampshire in 1989 after a 40-year absence, and continue to nest in several New Hampshire locations each year. In New Hampshire, bald eagles occur in relatively undisturbed forests along major rivers and lakes or near the coast. Eagles perch on, hunt from, and nest on tall coniferous and deciduous trees or snags near water. They prey primarily on fish and waterfowl, but are also noted for their scavenging. In winter, they leave the breeding areas and congregate in areas with large expanses of unfrozen, open water. A forest stand that offers protection from inclement winter weather is needed for communal night roosting. Night roosts are most often found near foraging areas, but may be further away if the roost is more protected. Bald eagles are observed each winter in the Androscoggin, Connecticut and Merrimack River Valleys, on Great Bay, and in the Lakes Region. Non-breeding adults and immature eagles are observed sporadically throughout the state year-round, including Great Bay. The Lamprey River may provide eagle foraging habitat at various times of the year. Flow changes in the Lamprey River that affect fish populations may have a slight impact on this very mobile bird of prey. This will be interpreted from the MesoHABSIM model.

Sedge Wren (Cistothorus platensis)

The sedge wren, a state endangered species, uses densely vegetated sedge meadows, wet hayfields, upland margins of ponds and marshes, and coastal brackish marshes, preferring drier marshes or wet meadows where there is little standing water and the ground is damp. Sedge wrens have low fidelity to both breeding and wintering sites, and readily abandon areas that become too wet or too dry through water level fluctuation. Meadows greater than 2 acres are preferred. Nesting in the northeast is low to the ground (within a foot), and initiated in late June or July and may coincide with seasonal stability of water levels in preferred habitats. Agricultural land borders the Lamprey in several locations, but may only be hydrologically connected in a few of these, notably near Lee Hook Road and north of Moat Island. The location of potential sedge wren habitat will need further investigation. Evaluation of flow effects will occur through the Floodplain Transect Model.

Pied-billed Grebe (Podolymbus podiceps)

Preferred habitat for the State endangered Pied-billed grebe is densely vegetated emergent and deep marsh interspersed with open water that is more than 12 acres in size ((Degraaf and Yamasaki 2001; Banner 1998). To the extent that such a marsh is dependent on river flow, this marsh bird species would be flow dependent. A preliminary inspection of aerial photos of the Lamprey River floodplain indicates that there are several marshes that could be habitat for the Pied-billed grebe, and some of these have a direct connection to the Lamprey River. The evaluation of flow dependency for the Pied-billed grebe is similar to that for Floodplains and Emergent Wetlands so the procedure detailed in the Floodplain Transect Model will be used to evaluate this species. Specific needs of the Pied-billed grebe are that standing water must always be present.

Vegetation

Much of the information regarding RTE vegetation was obtained from records provided by the NHNHB in 2005 and from a comprehensive report prepared by Sperduto and Crow (1994) of the Bureau. Individual RTE plant species are included, as well as one Exemplary Natural Community. Other natural communities are discussed in Section 3.1.5 Natural Communities and Wildlife Habitat.

Climbing Hempweed (Mikania scandens)

This state listed threatened plant species was found in 1994, in a wetland along a tributary to the Lamprey River. Although this climbing facultative-wetland plant is likely flow dependent, it is not clear how influential the Lamprey River flows are on this wetland system. This species may not be Lamprey flow dependent, and further investigation is needed.

Small-crested Sedge (Carex cristatella)

This state listed threatened plant species is typically found in meadows, rich woods and along pond margins. The plant has not been relocated where it was historically identified in 1942. There is some evidence that it may have been misidentified and this will be reviewed with the NHNHB.

Star Duckweed (Lemna tricsulca)

Historical records indicate this floating leaved aquatic bed species was collected from a tributary stream to the Lamprey River, but it was not observed in this location or elsewhere in the river in 1994 (Sperduto and Crow 1994). This obligate, state endangered species is most likely to be found in quiet backwaters and slow moving ditches.

Sharp-flowered Mannagrass (Glyceria acutiflora)

This state listed endangered grass species is found in shallow water in ponds and streams, and blooms in June and July. The Natural Heritage Bureau database indicates that is was last observed in the Lamprey in 1942 in fast-flowing shallow water. A related species was observed at this location in 1994, but not the target plant. This plant species may or may not be extirpated from this site.

Water Marigold (Megalodonta beckii)

This aquatic member of the composite family is found in ponds, streams and slow rivers, blooming in August to September. It is currently listed as an endangered species in New Hampshire. It has been recorded from one particular location in the Lamprey River where it was locally abundant in 1994, and was also observed in a tributary stream above a culvert that hydrologically separates the plant community from the Lamprey River during most flows. We did not observe this species in 2005, but we likely missed its period of flowering.

Small Beggars tick (Bidens discoidea)

A new station was located for this flowering facultative wetland species in 1994 in the project area, but it does not appear on the current RTE list of plants for New Hampshire, and presumably was removed from the list as it has been observed at numerous new sites.

Knotty Pondweed (Potamogeton nodosus)

This state endangered aquatic plant is found in shallow to deep ponds and streams, and was recorded as recently as 2004 in this portion of the Lamprey River. In 1994, the historic record was reconfirmed and found to be locally abundant in rapids throughout the study area, typically associated with riverweed (*Podostemum ceratophyllum)* and white water crowfoot *(Ranunculus trichophyllus*).

Slender Blueflag (Iris prismatica)

This state listed threatened species is found in brackish to fresh wet meadows, bogs, pond margins and wooded swamps. It blooms in June and July. This species was not mentioned in the 1994 survey by the NHNHB. A search for this flow dependent species will be undertaken in the summer of 2006.

Natural/Ecological Communities

Swamp White Oak (Quercus bicolor) Floodplain Forest

Floodplain forests dominated or co-dominated by swamp white oak are state and regionally rare, classified as S1 (Sperduto and Nichols 2004). These floodplain communities average approximately 1 to 6 feet above the main river channel. Based on the characteristic flora observed during the preliminary IPUOCR survey in the known swamp white oak community along a tributary to the Lamprey, both high and low variants of this community are present. This swamp is temporarily to seasonally flooded, and the degree to which it is dependent on Lamprey River flows is undetermined. Several slow streams flow through the swamp into the Lamprey River. This site, described as outstanding by the Natural Heritage Bureau, is the only swamp of its kind known from the watershed. Many of the other plants are typical of the lower floodplain forests found along the Lamprey River. Floodplain forests are dependent on spring floods to provide nutrients seasonally and discourage colonization of upland species. The flood intensity and duration of flooding are typically lower than for silver maple floodplain forests on larger rivers, and the flooding may occur earlier in the year.

Reduction in spring floods over long periods or increases in flooding intensity or duration may alter the plant community. The low elevation variant type may be more susceptible to affects from changes in flow. The relationship between flows in the tributary and flows in the Lamprey River will be explored during the flow analysis, and the effects of flow on the swamp white oak floodplain forest will be assessed using the Floodplain Transect Model, if appropriate.

3.1.7 Public Water Supply

In the New Hampshire Laws of 1965, Chapter 332, the New Hampshire Legislature preserved the Lamprey River water for seven towns through which it runs. This law will form a basis for these seven towns to expect the Lamprey River to supply water in an amount adequate to support domestic potable water needs. At this writing, the Durham/UNH water system makes a direct withdrawal from the Lamprey River from the impoundment behind Wiswall Dam. The Town of Newmarket has the ability to withdraw from Follett's Brook, the Piscassic River, and the Lamprey River (below the designated segment), and they have historically done so. The Town of Newmarket has been searching for new water sources for the past decade, and may investigate using Lamprey River water for artificial recharge of their Newmarket Plains aquifer. Newmarket has a water treatment plant located on the Piscassic River that can treat surface water, however the plant is rarely used due to a variety of reasons. Due to strong regional development pressure, the Lamprey River will be studied as a water supply by towns extending as far west as Northwood and Deerfield.

Other towns (Epping, Raymond, and Newmarket) have groundwater supply wells that supply their respective water supply system. Drawdown from these well systems may either directly induce recharge from the river or may intercept groundwater that would normally discharge to the river. Both of these conditions could result in lower flows in the river.

Proposed Assessment Method for Public Water Supply

Records of the public water supply systems diverting surface water from the Lamprey River within the designated reach will be reviewed to evaluate the timing, magnitude and duration of withdrawals. The only existing direct withdrawal of river water for a public water supply in the designated segment is the Town of Durham/UNH withdrawal, which is located upstream of Wiswall Dam. The amount of water that the town of Durham/UNH is permitted to withdraw is restricted under its water quality certificate (#2001-001). For flows, measured at the Packer's Falls USGS gage, between 45 cfs and 21 cfs, the withdrawal cannot exceed 1.8 cfs, between flows of 21 cfs and 13 cfs the withdrawal cannot exceed 0.4 cfs and when flow is equal to or less than 13 cfs there can be no withdrawal. The maximum drawdown of the backwater behind the Wiswall Dam cannot exceed 6 inches, which the Town of Durham/UNH has requested that this be increased to 18 inches.

The impact of the withdrawal of water from the river by the Town of Durham/UNH will be evaluated using the results of the MesoHABSIM (fish, mussels and invertebrates) and the Floodplain Transect Method (wildlife, vegetation and natural/ecological communities).

For groundwater dependent systems the hydrogeologic investigation to be conducted as a part of Task 2 of the PISF study will result in a clearer delineation of the relationship between these wells and river flow: that is the ability of wells to induce recharge from the river. If these wells are substantially connected to the river and creating induced recharge, the influence of the operation of these wells on river flows and achieving instream flows will be examined further as part of the WMP. Although low river flow may be associated with low groundwater levels and therefore possibly lower well yields, maintaining high river flows in order to support enhanced well yields is an extremely inefficient mechanism and management strategy, and therefore is not considered.

The scope of the present study was clearly delineated to focus on large groundwater withdrawals within 500 ft of the designated river and its tributaries. It is recognized that groundwater withdrawals and instream flows are watershed issues, and that a complete study would assess the effects and management strategies of all water uses within the Lamprey River watershed. The complexity of this issue and the uncertainty involved in predicting low flow periods lead to the limitation that only wells within 500 feet of the river be included in this instream flow study. During average to wet periods, all water users may be satisfied and water may be stored. During low flow times, there may be habitat stress. Habitat stress may be relieved by reducing groundwater withdrawals.

However, one must recognize that the groundwater-river flow connection has a delayed response to the reduction in groundwater withdrawals: the farther wells are from the river, the longer the delay, and possibly the inability of the reduced groundwater withdrawals to relieve habitat stress. Stakeholder-NHDES discussions, prior to the performance of this instream flow study, recognized the complexity and reality of the groundwater-river flow connection, and these discussions resulted in the 500 foot limit for large groundwater withdrawals. There are very few registered wells that do not fall within 500 feet of the designated river or one of its tributaries.

3.2 NON-FLOW DEPENDENT ENTITIES

Non-flow dependent entities are defined as those entities that do not directly depend on a prescribed minimum flow for their existence or survival. In some instances, non-flow dependent entities are dependent on flow dependent entities (for example wildlife that feeds on fish); in this case, the prescribed minimum flow would be based on the fish. If flows are sufficient to support fish then the wildlife would be sufficiently protected. In other instances the IPUOCR is related to a water use but not completely dependent on it. For example, a golf course uses water for irrigation but will not close if sufficient water is not available. These IPUOCR are defined as non-flow dependent but will be addressed in the water management plan as water users.

3.2.1 Storage

The Wiswall Dam is the only dam included in the NHDES dam database that is located on the designated segment (NHDES 2004). Wiswall Dam is located south of where Wiswall Road crosses the Lamprey River in the southwest corner of the town of Durham (Figure 2-1). The dam is owned by the town of Durham and it is used as an emergency source of water. The dam is essentially operated as a run-of-the-river, although the town of Durham is permitted to lower water levels behind the dam during periods when it is diverting water subject to conditions of its water quality certification (401) permit (see section 3.1.7).

There are no large impoundments exclusively within the designated segment, although the Macallen Dam, located in Newmarket, does create a backwater effect in its lowermost section. There are a number of dams in the watershed, but only a few (Pautuckaway Lake and Mendums Lake) with large amounts of storage that could be accessed during low flow periods. The impoundments are essentially full most of the time precluding the need for water to refill after drawdown. As a result, impounded water bodies used primarily for water storage are not considered to be flow dependent.

Some of the dams are considered affected dam owners (ADOs) for purposes of this study, while others are not. Dams with impoundment areas of less than 10 acres are considered non-ADO dams. Options for the management of river flows in the designated segment with water from all available storage will be included in the WMP.

3.2.2 Recreation

Recreation resources in the vicinity of the designated segment include: Locations used for hiking, nature study, fishing access, picnicking, winter sports and such include:

- Doe Farm Forest, owned by the Town of Durham;
- Wiswall Road Area, owned by the Town of Durham;
- Packers Falls Recreational Area, owned by the Town of Durham;
- Thompson Farm, Durham;
- Ferndale Acres Campground, Lee;
- Lamprey River Campground, Lee;
- Wellington Campground, Lee;
- Piscassic Street Park, Newmarket.

The sites and activities listed above are not classified as flow dependent. The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will also be sufficient to preserve the scenic value of the river.

3.2.3 Conservation/Open Space

Open Space parcels include the following:

- Durham: The eighty acre Doe Farm Forest contains 750 feet of river frontage along with extensive trails. Within the town of Durham, there is an additional seven miles of river frontage that is largely undeveloped.

- Lee: Within the town of Lee, eight properties account for 7.8 miles of river frontage that is bordered by wooded habitat and fields.

The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of the river.

3.2.4 Maintenance and Enhancement of Aquatic and Fish Life

Management of Exotic/Invasive Species

There are exotic and invasive species of vegetation and invertebrates present in New Hampshire, which have the potential for causing harm to the watershed. These species can be found listed on the New Hampshire Department of Environmental Services website. For the purposes of this project, these species are not IPUOCRs, although some are flow dependent. Rather, these species are threats to an IPUOCR – namely the communities of native plants and their habitat value. Maintenance and protection of these natural communities (and control of invasives) is assumed to be facilitated under the NFP, which should favor the adapted native plants. But invasive species may be favored when deviations from the natural flow paradigm occur. The potential for increases in the species mentioned below will be evaluated during the Floodplain Transect/seasonal water level modeling.

Several wetland and upland invasive species were observed during the field reconnaissance, including purple loosestrife (*Lythrum salicaria*), a species that relies on water transport of seed to spread and germinates in seasonally exposed mudflats. This is a perennial species that increases in periods of low flow, and could become more abundant if low water conditions are prolonged. Japanese knotweed (*Polygonum cuspidatum*) is a persistent perennial that spreads rapidly by rhizomes, fragments of which are often transported by water. Though such transport is possible at any flow, it is most likely to occur at high flows. The wind dispersed seed rarely germinates. This plant was observed on the riverbank in some locations, and is likely to spread regardless of flow. These and several other invasive species, including common barberry (*Berberis vulgaris*) and European buckthorn (*Frangula alnus),* were observed during the detailed vegetation assessments performed in 1993 and 1994 for the National Park Service (Chase 1993, Sperduto and Crow 1994). No invasive submerged aquatic macrophytes were recorded. A flow regime that encourages a healthy native community of flora and fauna in the designated segment will discourage the spread of exotic/invasive species.

3.2.5 RTE: Fish, Wildlife, Vegetation or Natural/Ecological Communities

Wildlife

Peregrine Falcon (Falco peregrinus)

The state endangered peregrine falcon has been observed in the four lower Lamprey towns (NHDES 2004), and may be observed in open country, from coastal lowlands to mountainous high country. After the population was decimated by the effects of DDT, breeding pairs in New Hampshire were re-established through a captive breeding program and are again present at some of their traditional breeding cliffs. The nest is often a hollow, unlined scrape on a cliff, ledge or rocky outcrop. Abandoned raven or hawk nests in high locations are occasionally used, as well as roofs and ledges of city buildings and large bridges. The same nest site may be used for many years. There are no known nest sites along the Lamprey River. Peregrines feed on birds, bats, and dragonflies, capturing their prey in mid-air by diving and striking the prey with closed feet and plucking the prey from the air with sharp talons. Peregrines are not flow dependent.

Eastern hog-nosed snake (Heterodon platyrhinos)

The state threatened hognose snake can be found in sandy woodlands such as pine barrens and oak woods; fields, farmland and coastal areas. Sandy soils are an essential habitat characteristic. Toads are their preferred prey, although frogs, salamanders, small mammals, birds and invertebrates are also taken. One unconfirmed report of a hognose snake in the Lamprey River area was reported (NHDES 2004). The hognose snake is not flow dependent, although they may use sandy floodplain areas along rivers.

Non-RTE Wildlife

Several other birds of conservation concern in New Hampshire have been reportedly observed within the watershed or even floodplain of the Lamprey River. These include the red-shouldered hawk, whip-poor-will, bobolink, eastern meadowlark, least flycatcher, wood thrush and American redstart, species at risk due to habitat loss or other concerns. While not flow dependent, these species may find appropriate habitat along the Lamprey River. A great blue heron rookery is reportedly located in a large beaver marsh that adjoins the Lamprey River. While herons often build nests in flooded forested wetlands that may be hydrologically connected to a river, the presence of a particular water level is not generally considered critical, and rookeries are sometimes located in upland forests.

Informal observations of non-flow dependent reptiles and amphibians include several species of snake (smooth green snake, common garter snake, eastern ringneck, black racer, milk snake, and redbelly snake) and a salamander (redback salamander).

Vegetation

Philadelphia panic-grass (Panicum philadelphicum)

Philadelphia panic-grass flowers from June-October in a variety of habitats from dry open woods and fields to moist shores of lakes and streams. It is listed in New Hampshire as an endangered species that is widespread in its range, but historical in New Hampshire. It potentially occupies a wide range from Georgia to east Texas, north to Nova Scotia and southwestern Quebec, west to Ontario, Minnesota, Iowa, Kansas, and Oklahoma. Its broad habitat associations identify it as likely non flow dependent.

Northern blazing star (Liatris scariosa)

Northern blazing star, a state endangered species, grows in dry, open grassy habitat. In New Hampshire it is found primarily on sandplains in clearings or in dry open pitch pine and oak barrens. It also occurs on dry river bluffs, on gravelly slopes, and near railroad tracks in association with these areas. These are generally early-successional habitats, characterized by nutrient-poor, sandy soils that only support relatively sparse vegetation. Fire has historically played a role in maintaining these open habitats and seems to have a positive effect on this species as well. The plants are not tolerant of shade and decline in undisturbed areas where later-successional species such as shrubs and trees move in. This species is not associated with lower river channels or floodplains, and is not flow dependent.

Blunt-lobe woodsia (Woodsia obtusa)

The blunt-lobed woodsia is a state endangered species that is widespread and secure further south in the United States. This fern grows on rocks or cliffs in deciduous forests and is sometimes associated with other native ferns. At its northern limit in Canada, it appears to favor south facing slopes for milder weather. This species has been reported from a rock outcrop near the Lamprey River in a birch, ash, oak and hickory forest above the influence of river flows, and from approximately 4 other New Hampshire sites. This species is not flow dependent.

Missouri rock-cress (Arabis missouriensis)

Missouri rock-cress is one of several similar rock loving plants belonging to the Mustard family. It favors circumneutral bluffs, ledges or rocky woods in hardwood or mixed forests. There are some questions regarding the taxonomy and/or global rank of this state threatened species. This plant was recorded from a site near the Lamprey River, but searches during the vegetation inventory (Sperduto and Crow 1994) did not reveal any populations. Based on the preferred habitats, this plant is not flow dependent.

Downy false foxglove (Aureolaria virginica)

The state endangered downy false foxglove is reported to be parasitic on the roots of species of white oaks. This plant prefers dry-mesic, open oak, woodland slopes with a southern aspect, and tolerates/benefits from some periodic disturbances that maintain a relatively open canopy. This plant was reported along the Lamprey River, but was not found during the searches of 1994 (Sperduto and Crow 1994). The dry-mesic oak woodland slopes are likely to be above the zone influenced by river flow, and this species is not considered flow dependent.

3.2.6 Water Quality Protection/Public Health

The river generally supports its water quality classification, class B, at all locations. According to the Lamprey River Management Plan (LRAC 2006), certain sites exceeded acceptable limits for bacteria and are below limits for dissolved oxygen. The report also suggests that chlorophyll a concentrations are occasionally high and zinc criteria are sometimes exceeded during low flow periods. The recent 303d list of impaired waters (NHDES 2004) lists portions of the Lamprey as impaired with respect to pH, mercury, dissolved oxygen and bacteria. The biotic integrity of the waterbody does show signs of impairment and degradation. However, cold-water and pollutant intolerant non-game species are present in the Lamprey, indicating that chemical and physical water quality conditions are favorable to supporting a diverse cold and warm water fishery. Recent NHDES and Lamprey volunteer monitoring program water quality data will be reviewed to insure that this IPUOCR is still correctly classified as non-flow dependent.

3.2.7 Pollution Abatement

The Epping WWTF (wastewater treatment facility) is the only registered discharger to the Lamprey River and its point of discharge is located above the designated segment. The project team will review wasteload allocations and permits as well as Superfund reports (Keefe Environmental Services in Epping and Mottolo Pig Farm in Raymond) and relate prescribed protective flows to the discharge. The TMDL report for the Lamprey completed in 1995 (NHDES 1995) is expected to provide the most recent analysis. Regional wastewater plans with the potential to influence flows in the Lamprey will also be reviewed. Unless the findings of this review indicate otherwise, pollution abatement is considered to be non-flow dependent.

3.2.8 Aesthetic Beauty/Scenic

The designated segment of the Lamprey River is included in the National Wild and Scenic Rivers System, which is administered by the National Park Service. The large amount of undeveloped land along the Lamprey makes it a valuable resource in terms of scenic beauty. Particularly scenic areas include three waterfall areas: Wadleigh Falls in Lee and Wiswall and Packers Falls in Durham. Good views of the river are available at the Wadleigh Falls Road, Lee Hook Road, Wiswall Road and Packers Falls Road bridge crossings. The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of the river.

3.2.9 Cultural/Community Significance

The river is discussed in each of the municipal master plans and is recognized as a significant community resource. The Lamprey River Advisory Committee (LRAC) includes representatives from the towns of Durham, Epping, Lee and Newmarket. They are in charge of developing and implementing a river management plan under the New Hampshire State River Management and Protection Program. The Lamprey River Watershed Association (LRWA) plays a key role in the protection and preservation of the river. They are involved in land protection, water quality monitoring and publication of a layman's water quality monitoring guide, public education, recreational activities, assistance with waterfront development proposals and the Lamprey's designation as a Wild and Scenic River. As for the aesthetic beauty/scenic beauty entity, the prescribed flow will be sufficient to preserve the cultural and community significance of the river.

3.2.10 Historical or Archaeological

According to the New Hampshire Division of Historical Resources, New Hampshire Archaeological Inventory, there is one site of historical significance within 100 meters of the Lamprey River along the designated segment. This site is located in Durham (Wiswall Falls Mill Site – address restricted. Listed 03-18-1988). Historical and archeological information is sensitive in nature therefore specific site locations are not identified in public documents. Wiswall Falls has had some archaeological exploration, mostly 19th century artifacts, colonial material, and evidence of ancient Indian residence.

Wadleigh Falls in Lee, is recognized as one of the earliest and the states most important archeological sites. It is "rich in prehistoric cultural remains found in an undisturbed context". Although both sites are important historical or archeological resources, neither is considered to be flow dependent.

3.2.11 Hydrological/Geological

Aquifers

From Epping and westward, stratified drift aquifers underlie and parallel the Lamprey River. In the eastern watershed towns of Epping, Lee, Durham, Newmarket, and Newfields, the stratified drift aquifers form a patchwork across the region. Saturated thicknesses can range from a few feet to over one hundred feet. In some locations, the stratified drift is overlain by a marine clay, thereby confining the stratified drift aquifers in these locations. In general, the Lamprey River and its tributaries serve as discharge locations for both overburden and bedrock groundwaters. In some locations, the river can recharge aquifers, but this does not appear to be areally extensive except during river flood stages. Stratified drift can be highly transmissive (up to 10,000 square feet per day) and in some places yield 100's of gallons per minute to wells. Frequently, these same locations were used for waste disposal, rendering large portions of such formations contaminated.

The bedrock that underlies the watershed includes igneous and metamorphic rock formations. In general, the bedrock has low transmissivity (range of 1 to 100 square feet per day). However in locations having large fractures or fracture intersections, the bedrock can yield substantial amounts of water (over 400 gallons per minute). Bedrock is predominantly confined, except in outcrop areas, and therefore the bedrock commonly discharges to overlying features (wetlands, overburden, water bodies). Recharge to bedrock wells relies on these same features to yield water into the rock formations surrounding water well withdrawals.

During extreme low-flow events, aquifer recharge to the river (baseflow) will be reduced. Due to the relatively slow reaction of groundwater hydrology to surface water hydrology, for this study, this IPUOCR is not considered to be flow dependent.

3.2.12 Agricultural

Agricultural properties along the river include:

- Brady on Route 152 below Wadleigh Falls, Lee
- Athemore Dairy Farm, Lee Hook Road, Lee
- University of New Hampshire, Lee Hook Road, Lee
- Unnamed, Lee Hook Road, Lee

None of these properties are listed as reporting their water use and as a result are not considered to be flow dependent. The agricultural uses of water will be addressed in the WMP.

4.0 REFERENCES

Aadland, L.P. 1993. Stream habitat types: Their fish assemblages and relationship to flow. North American Journal of Fisheries Management 13:790-806.

AMC. 2002. AMC River Guide, New Hampshire and Vermont. 3rd edition. The Globe Pequot Press, Inc. Guilford, CT.

Arbuckle, K. E., and J. A. Downing. 2002. Freshwater mussel abundance and species richness: GIS relationships with watershed land use and geology. Canadian Journal of Fisheries and Aquatic Sciences 59:310-316.

Bain, M.B. & J.G. Knight. 1996. Classifying stream habitat using fish community analysis. pp-- 107-117. In: M. Leclerc, H. Capra, S. Valentin, A. Boudreau & Z. Cote (ed.) Ecohydraulics. 2000, 2nd International Symposium on Habitat Hydraulics, Quebec City, Canada.

Bain, M. and M. Meixler. 2000. Defining a Target Fish Community for Planning and Evaluating Enhancement on the Quingbaug River in Massachusetts and Connecticut. Report for Quingbaug River Study Agencies. Cornell University, Ithaca, NY.

Banner, A. 1998. Identification of Important Fish and Wildlife Habitats of Southern Maine. U.S. Fish and Wildlife Service Gulf of Maine Program Web Site.

Bovee, K.D. 1982. A guide to stream habitat analysis using the IFIM. U.S. Fish and Wildlife Service Report. FWS/OBS-82/26. Fort Collins, CO.

Brunke, M., A. Hoffmann, and M. Pusch. 2001. Use of mesohabitat-specific relationships between flow velocity and river discharge to assess invertebrate minimum flow requirements. Regulated Rivers-Research & Management 17:667-676.

Cairns, S. 2005. Personal Communication. New Hampshire Natural Heritage Inventory (NHI). Concord, NH.

Capra, H., B. Pascal and Y. Souchon. 1995. A new tool to interpret magnitude and duration of fish habitat variations. Regulated Rivers: Research and Management. 10: 281-289.

Carroll, D. M. 1993. Lamprey River Turtle Study. David Carroll, Warner, NH. 49 pp.

Carroll, D. M. 1994. Lamprey River Turtle Study. David Carroll, Warner, NH. 24 pp. plus attachments.

Carroll, D. M. 1996. Lamprey River Turtle and Ecology Investigations 1996: Principal Findings. For the National Park Service. David Carroll, Warner, NH. 16 pp. plus maps.

Carroll, D. M. 1998. Lamprey River Wild and Scenic Study (with extensions to overlapping Great Bay Partnership Initiatives). Report on 1998 Field Investigations/ David Carroll, Warner, NH. 26 pp. plus maps.

Carroll, D. M. 2000. Generalized map of wood turtle habitat/habitat use on Stevens Farm Property, Lee, New Hampshire. 5 pp.

Chase, V. 1993. An Ecological Inventory of the Lamprey River Corridor. A Report Prepared for the National Park Service. New Hampshire Natural Heritage Inventory. 20 pp. plus maps.

DeGraaf, R. M. and M. Yamasaki. 2001. New England Wildlife. Habitat, Natural History and Distribution. University Press of New England, Hanover, NH. 482 pp.

Gross, M.R. 1987. Evolution of diadromy in fishes. American Fisheries Society Symposium. 1:14-25

Hardison, B.S., and J.B. Layzer. 2001. Relations between complex hydraulics and the localized distribution of mussels in three regulated rivers. Regulated Rivers-Research & Management 17:77-84.

Hardy, T.B., R.C. Addley. 2001: Vertical integration of spatial and hydraulic data for improved habitat modelling using geographic information systems. Pp. 65–75 in Acreman, M.C. (Ed.): Hydroecology: linking hydrology and aquatic ecology. Proceedings of the Birmingham, United Kingdom, Workshop, July 1999. IAHS Publication No. 266.

Harper, D., C.D. Smith et al. 1995. The ecological basis for the management of the natural river environment. pp 219-238. In: D. Harper & A.J.D. Ferguson (eds.). The Ecological Basis for River Management. John Wiley & Sons, Chichester.

Lamprey River Advisory Committee (LRAC). 2006. Lamprey River Management Plan 2006 Update (Draft).

Lamprey Wild and Scenic River Study (LWSRS). 1995. Division of Rivers and Special Studies, National Park Service, Department of the Interior.

Lenz, BM. 1997. Feasibility of Combining Two Aquatic Benthic Macroinvertebrate Community Databases for Water-Quality Assessment. Fact Sheet FS-132-97. US Department of the Interior – US Geological Survey. Middleton, WI. http://wi.water.usgs.gov/pubs/FS-132-97/FS-132-97.pdf

Lobb, M.D., III, & D.J. Orth. 1991. Habitat use by an assemblage of fishes in a large warmwater stream. Transactions of the American Fisheries Society 120(1):65-78.

McGregor, S. W., and J. T. Garner. 2004. Changes in the freshwater mussel (Bivalvia : Unionidae) fauna of the Bear Creek system of Northwest Alabama and Northeast Mississippi. American Malacological Bulletin 18:61-70.

McRae, S. E., J. D. Allan, and J. B. Burch. 2004. Reach- and catchment-scale determinants of the distribution of freshwater mussels (Bivalvia : Unionidae) in south-eastern Michigan, USA. Freshwater Biology 49:127-142.

Naiman, R.J., S.E. Bunn, C. Nilsson, G.E. Petts, G. Pinay and L. Thompson. 2002. Legitimizing fluvial ecosystems as users of water: an overview. Environmental Management 30: 455-467.

NHDES. 1995. Lamprey River TMDL Study.

NHDES. 2004. Lamprey IPUOCR Entities-Preliminary List. October 7, 2004.

NHDES 2004. 303D list of Impaired Waters. http://www.des.state.nh.us/ WMB/swqa/2004/ pdf/Vol2/Rivers.pdf

NHDES. 2005. Lamprey Baseline Fish Community Report.

New Hampshire Fish and Game Department (NHFG). 2005. New Hampshire Wildlife Action Plan.

New Hampshire Fish and Game (NHFG). 2005. Wiswall Dam Aquatic Ecosystem Restoration Project.http://www.wildlife.state.nh.us/Newsroom/news_2005/News_2005_Q3/Wiswall_Dam_Public_Info_090805.htm.

New Hampshire Fish and Game Department. 2006. Freshwater Fishing Digest. 84 pp.

New Hampshire Odonates Club. 2004. http://home.comcast.net/~smirick/odeclub/nhodesclub.html

Nestler, J. et al. In press. First principles based attributes for describing a template to develop the reference river. River Research and Application.

Noon, J. Fishing in New Hampshire: a history. MooseCountry Press, Warner, New Hampshire, USA..

Olden, J.D. and N.L. Poff. 2003. Redundency and the choice of hydrologic indices for characterizing streamflow regimes. River Research Applications. 19: 101-121.

Page, L.M. and B.M. Burr. 1991. Freshwater Fishes. Houghton Mifflin Company, Boston, MA. 432 pp.

Pal, C., D. Swayne, B. Frey. 2001. The automated extraction of environmentally relevant features from digital imagery using Bayesion multi-resolution analysis. Advances in Environmental Research. 5(4): 435-444.

Patterson, C. 2005. Personal Communication. New Hampshire Fish and Game Department (NHFG). Durham, NH.

Parasiewicz, P. 2001. MesoHABSIM: A concept for application of instream flow models in river restoration planning. Fisheries 26:6-13.

Parasiewicz, P. 2005. Ecohydrology study of the Quinebaug River – Final Report for New England Interstate Water Pollution Control Commission. Ithica, NY. 385pp.

Parmalee, P. W., and R. R. Polhemus. 2004. Prehistoric and pre-impoundment populations of freshwater mussels (Bivalvia : Unionidaue) in the South Fork Holston River, Tennessee. Southeastern Naturalist 3:231-240.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestergaard, B. Richter, R. Sparks, J. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. Bioscience. 47: 769-784.

Poff, N.L. and J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences. 46(10): 1805-1818.

Poff, N.L., and J.V. Ward. 1990. Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity. Environmental Management 14: 629-645.

Richter, B.D., J.V. Baumgartner, D.P. Braun. 1996. A method for assessing hydrologic alteratoin within a river network.. Conservation Biology. 10: 1163-1174.

Richter, B.D., J.V. Baumgartner, J. Powell, D.P Braun. 1997. How much water does a river need?. Freshwater Biology. 37(1): 231-249.

Richter, B.D., J.V. Baumgartner, D.P. Braun, J. Powell. 1998. A spatial assessment of hydrologic alteration within a river network. Regulated Rivers: Research and Management. 14: 329-340.

Sabo, M.J. 2000. Threatened fishes of the world: *Notropis bifrenatus* (Cope, 1867) (Cyprinidae). Environmental Biology of Fishes 59:384

Scarola J. 1987. Freshwater Fishes of New Hampshire. New Hampshire Fish and Game Department, Concord, Hampshire, USA.

Sperduto, D. D. and G.E. Crow. 1994. A Vegetation Assessment of the Lamprey River Corridor in Epping, Lee, Durham and Newmarket, New Hampshire. National Park Service, Boston, MA. 94 pp.

Sperduto, D. D. and W. F. Nichols. 2004. Natural Communities of New Hampshire. New Hampshire Natural Heritage Bureau, Concord, NH. Pub. UNH Cooperative Extension, Durham, NH. 229 pp.

Strayer, D. L. 1999. Use of flow refuges by unionid mussels in rivers. Journal of the North American Benthological Society 18:468-476.

Strayer, D. L., J. A. Downing, W. R. Haag. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. Bioscience 54:429-439.

Taylor, J. 1993. The Amphibians and Reptiles of New Hampshire. New Hampshire Fish and Game Department, Concord. 71 pp.

The Nature Conservency. 2004. http://nature.org/wherewework/northamerica/states /newhampshire/news/news1521.html#Birding%20Field%20Trip.

Townsend, C.R., and A.G. Hildrew. 1994. Species traits in relation to a habitat templet for river systems. Freshwater Biology 31: 265-276.

Trout Unlimited. 2004. The New England Brook Trout: Protecting a Fish, Restoring a Region.

U.S. Army Corps of Engineers (ACOE). 2005. Draft Environmental Assessment for the Wiswall Dam Aquatic Ecosystem Restoration. 89 pp.

U.S. Fish and Wildlife Service. 2001. Gulf of Maine Watershed Habitat Analysis – Draft Sedge Wren Habitat Model. Gulf of Maine Coastal Program, Falmouth, Maine.

Vana-Miller, S.L. 1987. Habitat suitability index models: Osprey. U.S. Dept. Int., Fish and Wildlife Service. Biological Report 82(10.154). 46 pp.

Vaughn, C. C., and C. C. Hakenkamp. 2001. The functional role of burrowing bivalves in freshwater ecosystems. Freshwater Biology 46:1431-1446.

Vaughn, C. C., and C. M. Taylor. 1999. Impoundments and the decline of freshwater mussels: A case study of an extinction gradient. Conservation Biology 13:912-920.

Wicklow, B. 2005. Personal Communication. New St. Anselems College. Manchester, NH.

Zabel, R.W. 2002. Using “time travel” data to characterize the behavior of migrating animals. The American Naturalist. 159: 372-387.

APPENDIX A

Fish and Invertebrate Species, Characteristics, and Habitat

Biological Summary of Order (Odonata)

A. Life History

1. Eggs - usually several hundred to several thousand; either in water or in plants; usually hatch in several days to 1 month
2. Nymphal Stage (immature stage) - nymphs; usually approximately 1 year (ranges from 3 weeks to 5 years)
3. Adults
   A. Most species live 40 to 50 days
   B. Crawl out of water to molt
4. Number of generations per year - most univoltine (some semivoltine or merovoltine)
5. Time of emergence - most spring and summer (some early fall)
6. Delays in development – during periods of adverse abiotic conditions diapause in the egg stage may commence for periods up to 7 months.

B. Habitat and Habits

1. Adults – many disperse widely but return to spend most of adult life near preferred aquatic habitat (not necessarily their natal habitat); some fly almost all of the time, others perch for short periods between flights
2. Nymphs – dragonflies common in slow–moving flowing waters and standing waters; not many damselflies found in flowing waters; nymphs move rather slowly, if at all; lie in soft sediment or climb about in vegetation or plant debris

C. Food

1. Adults
   A. Capture insects with spines on front legs
   B. Large eyes, 360 degrees to capture prey
2. Nymphs - capture invertebrates (anything they can subdue) with hinged labium

D. Respiration of Immature Stages

Closed tracheal system with gills at end of abdomen; external in damselflies, internal in dragonflies

E. Behavior

Adults - male dragonflies defend territories; unique copulatory loop; some males remain with females during oviposition

F. Significance

Important source of food for many fish species. Odonates are also important predators of mosquitoes and other biting flies associated with aquatic habitats.

Key to Information

(f): Female.

(m): Male.

SL (Standard Length): The measured straight-line distance from the most forward point of the head to the hidden base of the tail, as indicated by the crease formed when the tail is bent to one side.

TL (Total Length): The measured straight-line distance from the most forward point of the head to the end of the tail fin, with the lobes of the tail fin compressed.

Reproductive Guild: A group with similar strategies to raise their young (i.e., parental care).

> *Nonguarders: Open substratum spawners: Pelagophils - Large quantities of non-adhesive, near-neutral or buoyant eggs are scattered in open water. No parental care of eggs.*
>
> *Nonguarders: open substratum spawners: Litho-pelagophils - Eggs are deposited on rocks and gravel, but eggs, embryos or larvae become sufficiently buoyant to be carried away from the spawning substrate by water currents. No parental care of eggs.*
>
> *Nonguarders: Open substratum spawners: Phyto-lithophils - Deposit eggs in relatively clearwater habitats on submerged plants, if available, or on other submerged items such as rocks, logs or gravel, where their embryos and larvae develop. No parental care of eggs.*
>
> *Nonguarders: Open substratum spawners: Phytophils - Scatter or deposit eggs with an adhesive membrane that sticks to submerged, alive or dead, aquatic plants or to recently flooded terrestrial vegetation. Sometimes woody debris. No parental care of eggs.*
>
> *Nonguarders: Open substratum spawners: Psammophils - Usually small eggs with an adhesive membrane that are scattered directly on sand and/or the fine roots of plants that hang over the sandy bottom. No parental care of eggs.*
>
> *Nonguarders: Brood Hiders: Lithophils - Eggs are hidden in specially constructed places. In most cases the hiding places (called redds in salmonids) are excavated in gravel by the female. No parental care of eggs*
>
> *Nonguarders: Brood Hiders: Speleophils - Usually few large eggs with an adhesive membrane that are hidden in crevices. No parental care of eggs.*
>
> *Guarders: Substratum choosers: Lithophils - Choose rocks for attachment of their eggs. Eggs are guarded, and possibly and ventilated.*
>
> *Guarders: Substratum choosers: Phytophils - Choose plants for attachment of their eggs. Eggs are guarded, and possibly and ventilated.*
>
> *Guarders: Nest spawners: Polyphils - No particular nest building material or substrate is chosen, however, a nest is constructed and the nest and eggs are guarded.*
>
> *Guarders: Nest spawners: Lithophils - Eggs are deposited on cleaned areas of rocks or in pits dug in gravel. Nest is guarded.*

Guarders: Nest spawners: Ariadnophils - The nest building male has the ability to spin a viscid thread from a kidney secretion, which binds the nest of different material together. The eggs are guarded and ventilated by the male, who also guards the young once they hatch.

Guarders: Nest spawners: Phytophils - Eggs are deposited in nests constructed above or on a soft muddy bottom, often amid algae or other exposed roots of vascular plants. Nest is guarded.

Guarders: Nest spawners: Speleophils - These fishes guard a clutch of eggs in natural holes or cavities, in specially constructed burrows, or where deposited on a cleaned area of the undersurface of flat stones.

Fresh Water Eel Family *(Anguillidae)*

American Eel *(Anguilla rostrata)*
The American eel has a catadromous life strategy; that is, the eggs hatch in the sea, the young migrate to freshwater to grow, and the adults return to the sea to spawn.

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	top carnivore
Habitat Preference	near cover over muddy, silty bottoms of lakes, rivers and creeks; preferred water temperature ~19.0 ºC
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	marine
Spawning Season	winter
Spawning Months	January-March
Spawning Temp	~17º C
Nursery habitat(s)	marine; estuarine; riverine
Diet	na
Age at maturity (yrs)	3-10 (m), 4-18(f)
Adult Length (cm)	25-40 TL (m), 70-100 TL (f)

Sucker Family *(Catostomidae)*

White Sucker *(Catostomus commersoni)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	rocky pools and riffles of creeks and rivers; lake embayments; preferred water temperature ~22ºC
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	lacustrine; riverine, migrate upstream to tributaries, or shoal areas if tributaries are not available
Spawning Season	spring
Spawning Months	April-May
Spawning Temp	~7-10ºC
Nursery habitat(s)	lacustrine; riverine
Diet	benthic invertebrates, fish eggs, larval midges, detritus
Age at maturity (yrs)	2-3 (m), 3-4 (f)
Adult Length (cm)	30.5-50.8 TL

Creek Chubsucker *(Erimyzon oblongus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	creeks, streams, and lakes with moderate aquatic vegetation
Reproductive Guild	na
Spawning Habitat(s)	lacustrine; riverine, gravel runs; young move to downstream habitats after hatching
Spawning Season	spring
Spawning Months	na
Spawning Temp	na
Nursery habitat(s)	lacustrine; riverine
Diet	plant material, a wide variety of aquatic and terrestrial invertebrates
Age at maturity (yrs)	na
Adult Length (cm)	Usually less than 22.8 TL

Sunfish and Black Bass Family *(Centrarchidae)*

Rock Bass *(Amblolpites rupestris)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	top carnivore
Habitat Preference	clear, rocky-bottomed runs and flowing pools of small to large rivers with; shallow, rocky and areas of lakes
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring
Spawning Months	June
Spawning Temp	~15.5-21.1ºC
Nursery habitat(s)	lacustrine; riverine
Diet	generally, smaller individuals consume aquatic invertebrates, primarily zooplankton, and occasionally small fish, larger individuals mainly feed on crayfishes and fishes
Age at maturity (yrs)	1-3
Adult Length (cm)	15.2-30.5 TL

Banded Sunfish *(Enneacanthus obesus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	Lowland, weedy lakes, quiet weedy backwaters of lowland brownwater streams.
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring-summer
Spawning Months	April-July
Spawning Temp	~11-28ºC
Nursery habitat(s)	lacustrine; riverine
Diet	wide range of small aquatic invertebrates, especially those bottom dwelling or in vegetation
Age at maturity (yrs)	1-2
Adult Length (cm)	7.6-8.9 TL

Redbreast Sunfish *(Lepomis auritus)*

General Habitat(s)	lacustrine; riverine
Pelagic	na
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	clean water with rocky substrates; ponds, lakes, slow moving sections of streams and rivers; tend to avoid heavily vegetated areas
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	sheltered areas: rocks and woody debris; build nests in sand or gravel substrate
Spawning Season	spring-summer
Spawning Months	May-august
Spawning Temp	na
Nursery habitat(s)	lacustrine; riverine
Diet	wide variety of larval and adult aquatic insects, including mayflies, caddisflies, midges, flies, mosquitoes, beetles, and dragonflies; scuds, aquatic snowbugs, mollusks, and small fishes occasionally eaten
Age at maturity (yrs)	na
Adult Length (cm)	10.1-20.3 TL

Pumpkinseed *(Lepomis gibbosus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	warm, shallow, vegetated lakes and ponds; quiet vegetated pools of creeks and small rivers; preferred water temperature ~26.0°C
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine; sand or gravel substrate
Spawning Season	spring-summer
Spawning Months	May-August
Spawning Temp	~20-28ºC
Nursery habitat(s)	lacustrine; riverine
Diet	wide range of aquatic invertebrates, especially those bottom dwelling or in vegetation
Age at maturity (yrs)	1-3
Adult Length (cm)	12.7-19.0 TL

Bluegill *(Lepomis macrochirus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	warm, shallow, vegetated lakes and ponds; quiet vegetated pools of creeks and small rivers; preferred water temperature ~26.0°C
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine; sand or gravel substrate
Spawning Season	spring-early fall
Spawning Months	May-September
Spawning Temp	~20-28ºC
Nursery habitat(s)	lacustrine; riverine
Diet	wide range of aquatic invertebrates, especially those bottom dwelling or in vegetation, small fishes, fish eggs, and aquatic vegetation
Age at maturity (yrs)	1-3
Adult Length (cm)	12.7-23.0 TL

Smallmouth Bass *(Micropterus dolomieu)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	top carnivore
Habitat Preference	clear, gravel-bottomed runs and flowing pools of small to large rivers; shallow, rocky and sandy areas of lakes; preferred water temperature ~30°C
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring
Spawning Months	May-June
Spawning Temp	~13-20ºC
Nursery habitat(s)	lacustrine; riverine
Diet	generally, smaller individuals consume aquatic invertebrates, primarily zooplankton, and occasionally small fish, larger smallmouths mainly feed on crayfishes and fishes
Age at maturity (yrs)	3-5 (m), 4-6 (f)
Adult Length (cm)	25.4-40.6 TL

Largemouth Bass (Micropterus salmoides)

General Habitat(s)	Lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	Top carnivore
Habitat Preference	clear, warm, shallow lakes, bays, ponds, marshes and backwaters and pools of creeks and small to large rivers; often associated with soft mud or sand substrate and dense aquatic vegetation; usually at depths <6 m; preferred water temperature ~30°C
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	Lacustrine; riverine
Spawning Season	Spring
Spawning Months	May-June
Spawning Temp	~17-22ºC
Nursery habitat(s)	Lacustrine; riverine
Diet	Young feed primarily on aquatic invertebrates and small fishes, as they mature fish become a greater part of their diet, sometimes larger individuals consume small mammals and birds
Age at maturity (yrs)	3-4(m), 4-5 (f)
Adult Length (cm)	30.5-53.3 TL

Black Crappie *(Pomoxis nigromaculatus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	Top carnivore
Habitat Preference	Quiet, weedy waters of lakes, ponds, and streams
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine; sand or mud bottom, 3-8 feet deep, partly vegetated
Spawning Season	spring
Spawning Months	May-June
Spawning Temp	~14.4-17.7ºC
Nursery habitat(s)	lacustrine; riverine
Diet	wide range of aquatic invertebrates, and small fishes
Age at maturity (yrs)	2-4
Adult Length (cm)	12.7-30.5 TL

Herring Family *(Clupeidae)*

Blueback Herring *(Alosa aestivalis)*
The blueback herring is an anadromous fish, living in the ocean and migrating to freshwater to spawn. Juveniles remain in freshwater to mid-fall before migrating to sea.

General Habitat(s)	Marine; riverine
Pelagic	yes
Thermal Regime	na
Trophic Class	Generalist feeder
Habitat Preference	Gregarious; little is known about their specific habits and movements in Atlantic coastal waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	riverine
Spawning Season	Spring-early summer
Spawning Months	Late May-June
Spawning Temp	~17.7-23.8ºC
Nursery habitat(s)	riverine
Diet	Freshwater: small invertebrates; Saltwater: planktonic crustaceans, shrimps, and fish larvae
Age at maturity (yrs)	2-3
Adult Length (cm)	~20.0-30.0 TL

Alwife *(Alosa psuedoherangus)*
The alwife is an anadromous fish, living in the ocean and migrating to freshwater to spawn. Juveniles remain in freshwater until mid-fall before migrating to sea.

General Habitat(s)	Marine; riverine;
Pelagic	yes
Thermal Regime	na
Trophic Class	Generalist feeder
Habitat Preference	Gregarious; little is known about their specific habits and movements in Atlantic coastal waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	Lacustrine; riverine
Spawning Season	Spring
Spawning Months	May-early June
Spawning Temp	~8.8-12.2ºC
Nursery habitat(s)	Lacustrine; riverine
Diet	Freshwater: small invertebrates; Saltwater: planktonic crustaceans, shrimps, and fish larvae
Age at maturity (yrs)	3-4
Adult Length (cm)	~20.0-30.0 TL

American Shad *(Alosa sapidissima)*
The American shad is an anadromous fish, living in the ocean and migrating to freshwater to spawn. Juveniles remain in freshwater until early fall before migrating to sea.

General Habitat(s)	Marine; riverine;
Pelagic	yes
Thermal Regime	na
Trophic Class	Generalist feeder
Habitat Preference	Gregarious; little is known about their specific habits and movements in Atlantic coastal waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	Lacustrine; riverine
Spawning Season	Spring-early summer
Spawning Months	May-June
Spawning Temp	~14.0-21.0ºC
Nursery habitat(s)	riverine
Diet	Freshwater: small invertebrates; Saltwater: planktonic crustaceans, shrimps, and fish larvae
Age at maturity (yrs)	2-5
Adult Length (cm)	~40.0-50.0 TL

Carp and Minnow Family *(Cyprinidae)*

Common Shiner *(Luxilus cornutus)*

General Habitat(s)	riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	pools near riffles in clear, cool creeks and small to large rivers; preferred water temperature ~30ºC
Reproductive Guild	Nonguarders: brood hiders: Lithophils
Spawning Habitat(s)	riverine
Spawning Season	spring -summer
Spawning Months	May-July
Spawning Temp	~16- 24ºC
Nursery habitat(s)	riverine
Diet	feed mainly at surface or in midwater; opportunistic feeders: aquatic insects both adults and larvae are primary food source, occasionally small fishes and some plant material
Age at maturity (yrs)	1-3
Adult Length (cm)	7-14 TL

Golden Shiner *(Notemigonous crysoleucas)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	clear, weedy, quiet waters of lakes, ponds, reservoirs, pools in slow moving rivers and streams; preferred water temperature~24ºC
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	summer
Spawning Months	June-August
Spawning Temp	~20-27ºC
Nursery habitat(s)	lacustrine; riverine
Diet	feed mainly at surface or in midwater, feed mainly on zooplankton, adults sometimes feed on insects and small fishes
Age at maturity (yrs)	2-3
Adult Length (cm)	10-15 TL

Bridle Shiner *(Notropis bifrenatus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	Generalist feeder
Habitat Preference	Weed beds near margins of lakes, backwaters, sluggish weeded streams; slow to moderate current; muddy substrates
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	Spring-summer
Spawning Months	May-July
Spawning Temp	~14-27ºC
Nursery habitat(s)	lacustrine; riverine
Diet	tend to feed near bottom and consume small crustaceans, small aquatic or terrestrial insects, algae
Age at maturity (yrs)	1-2
Adult Length (cm)	3.5-5 TL

Blacknose Dace *(Rhinichthys atratulus)*

General Habitat(s)	riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	runs, pools, and riffles; in clear swiftly flowing creeks and small rivers with gravelly substrate
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	riverine
Spawning Season	spring
Spawning Months	May-June
Spawning Temp	~15-22ºC
Nursery habitat(s)	riverine
Diet	feed on a wide variety of aquatic invertebrates and terrestrial insects, aquatic fly larvae are a favored prey
Age at maturity (yrs)	1-2
Adult Length (cm)	6-7.6 TL

Longnose Dace *(Rhinichthys cataractae)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	benthic insectivore
Habitat Preference	Cobble, boulder or gravel riffles of clean swiftly-flowing, creeks and small to medium rivers; rocky shores of lakes; preferred water temperature ~21ºC
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	riverine
Spawning Season	spring-summer
Spawning Months	May-July
Spawning Temp	~11-23ºC
Nursery habitat(s)	riverine
Diet	diet consists primarily of immature aquatic insects that cling to rocks and boulders; chief predator of larval blackflies and midges, but will also prey on other small aquatic invertebrates
Age at maturity (yrs)	2-3
Adult Length (cm)	6.5-11.8 TL

Fallfish *(Semotilus corporalis)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	gravel and cobble bottom pools and runs of small to medium rivers; margins of lakes, ponds, or reservoirs; preferred water temperature ~22ºC
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	riverine: gravel, cobbles; adhesive eggs that stick to the nest
Spawning Season	spring
Spawning Months	May-June
Spawning Temp	~14-19ºC
Nursery habitat(s)	riverine
Diet	omnivorous, eating mostly plankton until they reach~ 1.5 inches in TL, gradually switching to larger foods such as: algae, insects, crayfish, and fishes
Age at maturity (yrs)	3 (m), 4 (f)
Adult Length (cm)	15.5-25.5 TL

<u>Pike and Pickerel Family *(Escidae)*</u>

Redfin Pickerel *(Esox americanus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	top carnivore
Habitat Preference	typically live in ponds and quiet backwaters of lowland streams; prefers still, shallow waters with dense vegetation; can occur in brackish and acidic waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring
Spawning Months	March-May
Spawning Temp	~8-11ºC
Nursery habitat(s)	lacustrine; riverine; swampy, marshy, or flooded areas with abundant submerged vegetation
Diet	juveniles feed on smaller invertebrates and fishes, adults are highly picivorous, large pickerel will eat small mammals, frogs, and snakes
Age at maturity (yrs)	na
Adult Lenth (cm)	30.0 TL

Chain Pickerel *(Esox niger)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	top carnivore
Habitat Preference	typically live in ponds and quiet backwaters of medium to large rivers, less common in smaller streams, can occur in brackish waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring
Spawning Months	March-May
Spawning Temp	~8-11ºC
Nursery habitat(s)	lacustrine; riverine; swampy, marshy, or flooded areas with abundant submerged vegetation
Diet	juveniles feed on smaller invertebrates and fishes, adults are highly picivorous, large pickerel will eat small mammals, frogs, and snakes
Age at maturity (yrs)	na
Adult Lenth (cm)	33.0 TL

<u>Bullhead Catfish Family *(Ictaluridae)*</u>

Yellow Bullhead *(Ameiurus natalis)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	pools and backwaters over soft substrates in sluggish creeks and small to large rivers; oxbows, ponds, impoundments and heavily vegetated areas of shallow bays and small lakes; preferred water temperature ~28ºC
Reproductive Guild	Guarders: Nest spawners: Speleophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	Spring
Spawning Months	May-June
Spawning Temp	~23-27ºC
Nursery habitat(s)	lacustrine; riverine
Diet	insects, crustaceans, mollusks, and small fishes, as well as some plant material
Age at maturity (yrs)	2-3
Adult Length (cm)	17.8-34.3 TL

Brown Bullhead *(Ameiurus nebulosus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	pools and sluggish runs over sand to mud substrates in creeks and small to large rivers; impoundments, ponds and lake embayments; preferred water temperature ~25-27°C
Reproductive Guild	Guarders: Nest spawners: Speleophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	Spring
Spawning Months	May-June
Spawning Temp	~21-25ºC
Nursery habitat(s)	lacustrine; riverine; young remain in areas with aquatic vegetation through the end of their first summer
Diet	omnivores feed on wide variety of animal and plant material
Age at maturity (yrs)	2-3
Adult Length (cm)	19.3-35.6 TL

Temperate Bass Family *(Percichthydae)*

White Perch *(Morone americana)*
The white perch has a semi-anadromous life strategy; the fish lives its adult life in saltwater estuary habitats and migrates to tidal freshwater and slightly brackish habitats to spawn in the spring.

General Habitat(s)	Lacustrine; riverine; estuarine
Pelagic	semi
Thermal Regime	coolwater
Trophic Class	Top carnivore
Habitat Preference	Brackish bays, river mouths, estuaries, and muddy ponds accessible from the sea
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	Lacustrine; riverine; estuarine
Spawning Season	Spring
Spawning Months	May
Spawning Temp	~12.7-14.9ºC
Nursery habitat(s)	Lacustrine; riverine; estuarine; shallow, vegetated or gravel-bottomed shorelines or shallows areas of streams, ponds, or estuaries
Diet	Freshwater: aquatic insects and fishes; Saltwater: shrimps, crabs, small squids, fish fry, and the eggs of other fishes
Age at maturity (yrs)	2-4
Adult Length (cm)	~25.0-35.0 TL

Perch Family *(Percidae)*

Yellow Perch *(Perca flavescens)*

General Habitat(s)	Lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	Top carnivore
Habitat Preference	lakes, ponds and pools of creeks and small to large rivers with moderate aquatic vegetation and clear water, young inhabit weedy shallows, while adults prefer rock ledges usually at depths less than 9 m; preferred water temperature ~ 21°C
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	Lacustrine; riverine: weedy areas
Spawning Season	Spring
Spawning Months	April-May
Spawning Temp	~6-12ºC
Nursery habitat(s)	Lacustrine; riverine
Diet	Diurnal carnivores, feeding on small aquatic insects, crustaceans, and small fishes
Age at maturity (yrs)	2-3 (m), 3-4 (f)
Adult Length (cm)	15.2-30.5 TL

Swamp Darter *(Etheostoma fusiforme)*

General Habitat(s)	Lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	Generalist feeder
Habitat Preference	Heavily weeded, shallow, protected coves of lakes and ponds; patches of vegetation in fast flowing streams
Reproductive Guild	Nonguarders: Open substratum spawners: Phyto-lithophils
Spawning Habitat(s)	Lacustrine; riverine: weedy areas
Spawning Season	Spring
Spawning Months	May
Spawning Temp	~12-15ºC
Nursery habitat(s)	Lacustrine; riverine
Diet	Small invertebrates and algae
Age at maturity (yrs)	1
Adult Length (cm)	2.5-5 TL

Lamprey Family *(Petromyzontidae)*

Sea Lamprey *(Petromyzon marinus)*
The sea lamprey, an anadromous, jawless fish, enters freshwater to spawn each spring where its juvenile progeny (ammoceote) spend 4-6 years burrowed in the mud filter-feeding on minute organisms before migrating to the ocean as adults.

General Habitat(s)	Marine; riverine;
Pelagic	yes
Thermal Regime	na
Trophic Class	Parasite
Habitat Preference	Little is known about this species specific habitat preferences at sea
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	Riverine; shallow, swift-running, stony stream sections
Spawning Season	Spring-early summer
Spawning Months	May-June
Spawning Temp	~12.0-23.0
Nursery habitat(s)	riverine
Diet	Blood and bodily fluids of host fish
Age at maturity (yrs)	5-8
Adult Length (cm)	~60.0-75.0 TL

Salmon, Char, and Tout Family *(Salmonidae)*

Rainbow Trout *(Oncorhynchus mykiss)*

General Habitat(s)	lacustrine; riverine
Pelagic	yes
Thermal Regime	coldwater
Trophic Class	Top carnivore
Habitat Preference	mid-waters of lakes; creeks and rivers with moderate flow, gravelly bottoms and riffle-pool habitat; preferred water temperature 11.3°C
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	riverine
Spawning Season	spring
Spawning Months	March-May
Spawning Temp	~5-13ºC
Nursery habitat(s)	Hatchery (reproducing populations in New Hampshire na) In Massachusetts reproducing populations are restricted to coldwater streams with high gradient (more than 75 feet per mile)
Diet	Aquatic and terrestrial insects; picsivory in lake dwelling adults
Age at maturity (yrs)	3-5
Adult length (cm)	36.1-73.4 TL

Atlantic Salmon *(Salmo salar)*

The Atlantic Salmon has an anadromous life history. Young salmon remain in freshwater for two or three years, descending to the sea as smolts. At sea, they live for one or two more years before they return to their natal streams to spawn.

General Habitat(s)	lacustrine; riverine; marine
Pelagic	yes
Thermal Regime	coldwater
Trophic Class	top carnivore
Habitat Preference	mid-waters of lakes; rocky runs and pools of small to large rivers; preferred water temperature 16.0°C
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	riverine: highly oxegenated, minimal pollution levels, and silt-free rocky or gravel substrate
Spawning Season	fall
Spawning Months	October- November (return to freshwater typically in May or June)
Spawning Temp	~4-10ºC
Nursery habitat(s)	Riverine
Diet	Young Atlantic salmon feed primarily on aquatic and terrestrial insects while they are in freshwater. Adult Atlantic salmon do not feed in fresh water prior to spawning.
Age at maturity (yrs)	3-6
Adult Length (cm)	53.8-74.4 TL

Brown Trout *(Salmo trutta)*

General Habitat(s)	lacustrine; riverine
Pelagic	yes
Thermal Regime	coldwater
Trophic Class	top carnivore
Habitat Preference	creeks and rivers with moderate flow, gravelly substrates and riffle-pool habitat, and lake shallows; preferred water temperature ~21°C
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	Riverine: spawning substrate with stones ranging from .25-3 inches in diameter
Spawning Season	fall
Spawning Months	October- December
Spawning Temp	~2-13ºC
Nursery habitat(s)	riverine
Diet	juvenile brown trout are primarily insectivorous, until the onset of picsivory
Age at maturity (yrs)	2-4
Adult Length (cm)	25.8-63 TL

Brook Trout *(Salvelinus fontinalis)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coldwater
Trophic Class	top carnivore
Habitat Preference	clear, cool, well-oxygenated streams, ponds and lakes with maximum water temperature less than 22°C; preferred water temperature 16.0°C
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	lacustrine; riverine: gravel riffles coarse sand and stone up to 4 inches in diameter
Spawning Season	fall
Spawning Months	September-November
Spawning Temp	~4-10ºC
Nursery habitat(s)	lacustrine; riverine
Diet	stream dwelling brook trout are primarily insectivores
Age at maturity (yrs)	15.2-44.2 TL
Adult Length (cm)	2-3